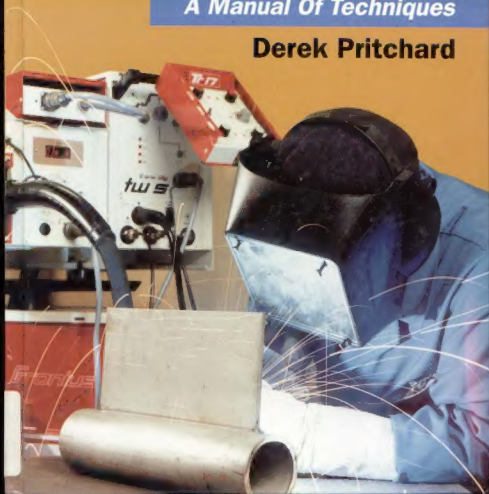


Soldering, Brazing & Welding

A Manual Of Techniques

Derek Pritchard



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1 WHAT IS WELDING?

To weld is to join two pieces of metal together. Further clarification of fundamental variations is necessary of course, which then denies a simple definition.

It can just involve pressure, but this is usually aided by some form of heating and varies from the blacksmith's fire weld to electrical resistance spot welding. Heating is also used to enable bonding to occur when soldering or brazing and to melt the metal in fusion welding. Heat energy sources can be

electrical, chemical, mechanical, light and sound.

So welding can be done hot or cold, with or without pressure and with or without melting, with or without filler addition, manually or automatically and so on, but it will certainly involve the joining of metal!

Welding is typically chosen for metal joining because it offers strength and permanency. However, in some cases these features may be undesirable and in others there may be an easier method.

Mechanical devices such as bolts, set pins, screws and so on offer some alternatives which are typically fairly easy to apply, and can be taken apart/reassembled easily, although they may perhaps lack the strength or the ability to retain fluids that welding offers.

Welding is rarely a recreational pursuit, but a means to an end (which may be recreational!), and it is relatively expensive and requires much practice to be done skilfully. It will only be adopted once all alternatives, too many to list and detail here, have been given adequate consideration.

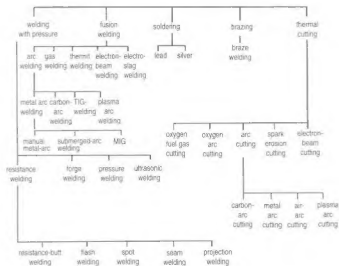
WHICH WELDING PROCESS?

This book assumes of course that welding has been chosen as the most appropriate



A typical welding situation

What is Welding?



Some of the more common welding processes

joining method but now a particular welding process needs to be selected. Again advantages and disadvantages are weighed against each other to establish the process with the optimum features for the task.

A British Standard lists over ninety different welding techniques/processes many of which are automatic or used in limited special situations.

This book deals with the common techniques in widespread use which require manual skill.

Features of Processes/Techniques

1. **Lead soldering** Quite easy, especially

on thin/light joints, good for dissimilar metals/thicknesses, low cost equipment. Relatively low strength.

2. **Silver soldering** Excellent with copper or brass but quite expensive.

3. **Brazing/braze welding** As soldering, but high strength and probably needs oxy-acetylene equipment. Less distortion than fusion processes.

4. **Oxy-acetylene** Gas welding; very versatile for heating, cutting, brazing and so on; high skill level – co-ordination of both hands needed.

5. **Manual metal arc (MMA)** Good for thick and dissimilar metals but tricky on thin metal and in acute corners.

6. **Metal inert gas(MIG)** Establishing optimum welding parameters needs much skill but it is easy to use, versatile and fast over a wide thickness range.

7. **Tungsten inert gas (TIG)** Needs much skill and is slow; used for high quality 'specialist' welding.

Weldable Metals

The ease with which a metal can be welded is known as its weldability and varies greatly.

All metals can be welded, with mild steel being the most common and readily weldable by all methods. Metals with high thermal conductivity require a high heat input and metals with refractory oxides need stronger fluxing. Some metals need special treatment because they are crack sensitive, and cast-iron especially may crack because it is very brittle.

The least success is experienced with very low melting point alloys, particularly when the exact composition is not known, and

commonly alloys which are zinc based.

Any thickness of metal can theoretically be welded but for practical purposes fusion welding below about 0.9mm is difficult, and above 25mm (1in) warrants special consideration in relation to suitable consumables, or the need for a faster machine process.

WHERE TO WELD

The classic fabrication workshop is constructed entirely of steel and concrete, with very minor quantities of combustible materials in the form of electrode cartons etc.

For the working environment to be safe, the planning of any welding operation demands to a greater or lesser extent attention to the following.

The Workshop

1. The flammability of the fabric of the building.



A fabrication workshop producing trailers.



Fire extinguishers, an essential part of the welder's kit.

2. The storage/location of flammable items.
3. Location of fire extinguishers.
4. Adequate access for emergency services.
5. Installation of welding and other electrical equipment with particular reference to the loading on the system and ensuring that all metal is at earth potential (earthed).
6. Fume extraction at all welding sources.
7. Adequate screening between arc welding and other personnel.

The Personnel

1. Knowledge of the safety policy and its procedures including the fire drill and evacuation procedure;
2. Basic first aid knowledge;
3. Training in welding health and safety.

Basically the operator needs to know how to prevent accidents, in particular those peculiar to welding, and how to deal with them should they arise.

Finally, on an electrical note, a single phase supply is perfectly adequate, but does restrict the size of welder that can be run on the supply. For faster welding of heavier materials a three phase supply/machine is necessary.

2 NON-FUSION JOINING METHODS

Most of this book is devoted to the making of high tensile joints where the strength is intended to match the parent metal. These are typically made by fusion welding, where the filler wire and parent metal both melt, flow together as a liquid mixture, and on solidifying form a homogeneous joint.

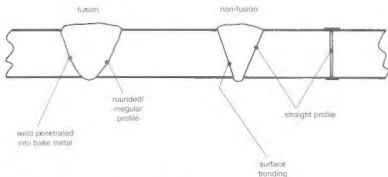
Since it is not always appropriate or possible to fusion weld metals together, the first sections deal with a group of non-fusion joining methods. They are:

1. Lead, or soft soldering
2. Silver, or hard soldering

3. Brazing
4. Braze, or bronze welding

In each of these methods the filler wire melts but the parent metal does not. Joint strength is achieved by 'bonding' or 'skin adhesion' and there is essentially no difference for example between solder and an adhesive, other than the need to heat solder in order to add it as a liquid. In each case a liquid is supplied to the joint which becomes solid and 'sticks' the items together.

The general trend is for an increase in melting point to be accompanied by an increase in tensile strength.



Cross-section through fused and non-fused butt joints.

LEAD SOLDERING

Historically the development of metals started with metals like tin and lead, and progressed to increasingly higher melting point materials which were more useful but more difficult to manufacture. Lead soldering has existed for hundreds of years, and rather than being superseded has become increasingly versatile and varied. It finds application in many alloy combinations, from joints as small as 150 microns on printed circuit boards to lorry radiator joints.

The following factors need to be considered when making a soldered joint:

1. Joint design/preparation
2. Heat source
3. Solder
4. Flux
5. Post cleaning.

Joint Design/Preparation

Surface Contact

Lead solder is weak in tension so soldering two thin edges butted together is unsatisfactory. All joints must be made with overlapped surfaces, where the contact area is made great enough to offset the lack of strength.

In some cases strength is gained mechanically, for example, a wire may be fed through

a hole in a terminal and then soldered. This idea is developed in sheet metal joints, which are totally self-secured and where the main function of solder is to seal the joint rather than hold it together.

Fit-Up

The overlapped surfaces must be in good contact. Gaps in excess of 0.25mm cause the solder to flow on each surface but not bridge across the gap. Soldering relies totally on capillary action, that is, the drawing of a liquid between two surfaces very close together, and is much too fluid to bridge gaps or build up like a weld bead. Capillary action can be ensured by using a clamp, vice, weight, press, binding wire or any device that will keep the surfaces in good contact.

Cleanliness

The best results will be obtained by having joint surfaces which are both mechanically and chemically clean, to allow the flux and solder to 'wet' evenly. Oxide and paint and so on can be removed by any abrasive means followed by degreasing with a solvent.

Heat Source

The two components of heat are (a) its intensity and (b) its volume. If bare skin is exposed to a red-hot spark or to a cup of boiling water then the spark has great inten-



Joint design for soldering

sity, and at hundreds of degrees Celsius is very hot; but the boiling water at only 100°C would inflict much more damage, because the volume of heat/amount of energy is so much greater. A change in heat is often required during welding and the decision is always one of whether more heat or hotter heat is necessary.

The heat source options for manual soldering are an iron, a flame, or a combination of both. A range of mass production sources using ovens or electric resistance etc. can be used combined with appropriate techniques.

The joint need only be heated to between 200 and 300°C, which must be supplied in the right volume to enable controlled melting of the solder.

Soldering Irons

Irons traditionally had a copper bit, but the life of a modern iron is extended by being alloyed or coated with a more corrosion-resistant metal. It is heated either internally electrically or externally with a flame, and physically may vary in section/mass to

hold/supply the right volume of heat.

Electric irons are rated in watts, from a 20-watt iron, which is small and suitable for light electrical connections, to a 200 watt iron, which is capable of joining thick sheet.

The shape of the bit is important. For fine electrical work it is pencil-like in section with a raked flat angle at the tip. Heavy sheet joints, on the other hand, require maximum contact so the tip end has large flat sides taked to a chisel edge.

Flame heating is best done in a purpose-made mains gas heater which provides a stable and gentle heat source. An oxy-acetylene (O/A) flame can be used but care is needed to prevent overheating, while a DIY or plumber's blowtorch will heat steadily, if somewhat slowly.

The bit is at the correct temperature when it will melt and hold a small quantity of solder. If too cold it will fail to melt solder, and when overheated solder melts instantly and runs off the bit. Not all irons are designed for continuous use. If overheated or heated for too long the bit oxidizes, becomes unstable and must be cooled and cleaned.



Types of soldering iron bit

Flame Heating

This is best done with a blowtorch, which will heat the work steadily and controllably, assuming the joint has enough mass to demand a flame or enable it to be used without damage to other parts of the component.

If the heating rate is slow then the heat supplied must be contained as much as possible. Placing the work on a firebrick surface rather than steel, working into a 'corner' built up of bricks or, at the extreme, building a brick furnace around the work will help conserve heat.

If it is necessary to resort to oxy-acetylene then the end of the flame furthest from the tip is used with a small nozzle.

This assumes that the work is relatively light but the intensity of O/A can be put to good use on heavy work, as required perhaps by the steam model engineer working in copper.

Joints which are difficult to heat with an iron may still be soldered with one if a flame is used to pre-heat and perhaps maintain a high ambient temperature, so that the heating required of the iron is reduced.

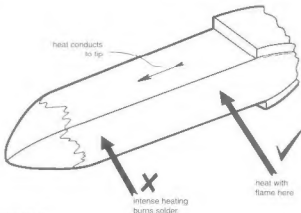
Oven Heating

Soldering can be largely automatic if the joint is preloaded with both solder and flux and placed in a furnace. The temperature of the component can be controlled very closely but it will of course be full heating rather than local.

Other heating methods include electric resistance, ultrasonic, induction, hot gas and focus infra-red soldering.

Types of Solder

To appreciate the differences between solders some knowledge of metals and alloys is



Flame heating a solid bit.

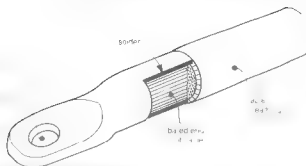
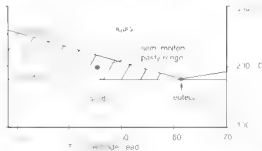


Diagram of a mechanical joint assembly showing a pin, a sleeve, and a nut.

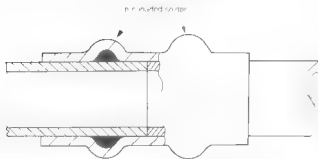


Common Solders

Types of Flux

T	Type	Uses
60/40	Sn/Pb	Electronic instrument assemblies
62/36/2	Sn/Pb/Bi	High class fine smithing
50/50	Sn/Pb	General purpose rings and sheet metal
40/60	Sn/Pb	Best with flame rather than gas
30/70	Sn/Pb	Plumbing - expanding wire pipe joints

Solder types and their uses



Solder Flux Paste

Prefluxing joints is often a good idea, but here solder particles suspended in the flux enable both to be preloaded. Heating now causes the joint to be made 'automatically'.

Post Cleaning

Removal of passive films may be necessary for appearance or because the joint has to be painted. This can be done with organic solvents. Reactive fluxes must always be removed. This is done with hot soapy water and a wire brush.

Making a Soldered Joint

The joint surfaces are cleaned, a suitable flux and solder chosen, and an iron of appropriate size and shape selected. The iron is prepared and heated, the joint 'wetted' and then joined together.

Preparing the Iron

If the iron to transfer solder it must first be coated in solder itself. An overheated iron is prepared by filing down to clean metal, and then the tip is coated in flux, heated and sol-

der applied. Excess solder can be wiped off with a damp rag or sponge which will leave a thin coating remains, flux residue and enable the tip to be checked for complete coverage. If a flame is being used for heating it should be directed to the base of the bit away from the tip to prevent oxidation of the solder.

Wetting the Surfaces

The joint may sometimes be made in a single operation but usually it is much easier if it is done in two stages by coating each surface in solder first, and then joining them together.

The first stage is often inaccurately referred to as 'tinning' and more correctly known as 'wetting' the surface. The technique can be useful when brazing too and ensures that each surface is distinctly coated and easily retrievable if it is not before commencing to making the joint.

Once solder has wetted the surface then it is simply a matter of joining solder to solder. Flux is applied to the surface at an early stage to prevent oxidation as it heats. The heated iron loaded with solder is placed on the metal and allowed to make maximum surface contact. As the metal reaches the temperature of

Non Fusion Joining Methods

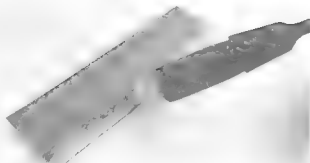
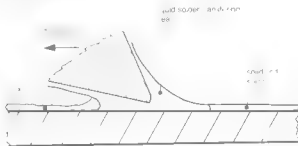


Fig. 1

Fig. 2



Joining Together

A small amount of passive flux is applied when the surfaces are overlapped and heated until they run together. When heated with an iron it will need to be loaded with further solder to transfer heat and fill any gaps. The iron is directed to one edge of the joint and held in position until the heat has conducted through the joint and the full width is molten. Then the iron is moved along the

joint. Heating may speed this process up but heating should not be rushed. Otherwise if a solder layer on the upper surface will oxidize before the lower one has melted. Note that some flux and a further addition of solder are still needed in this second stage.



Flame soldering a funnel under load

Cooling Rate

The best mechanical properties are obtained by fast cooling, which may also remove the degeneration of joints breaking apart because they are weak at high temperatures or have remained molten longer than expected.

Solderability of Common Metals

Copper

Readily soldered with good strength, copper's limiting factors are its high conductivity and the demand for a lot of heat which becomes noticeable with increase in mass thickness. Colour matching can be a problem.

Brass

These high copper alloys are again easy to solder, with less quantity of heat required than with copper but sharing the same disadvantages.

Steel

Steel is more difficult to solder than copper or alloys but is quite readily joined with any type of solder. Some coatings like tin or high lead (terne plate), are very easy, aged cadmium and zinc are difficult, and chrome impossible.

Galvanized Steel

Getting welder to wet with the zinc coating on galvanized steel is quite tricky and only possible when

1. Concentrated hydrochloric acid is used as the flux. This must of course be handled with care and oxidation of time be avoided.

The flux must not be added immediately prior to its use, because after only a few seconds of exposure to acid the surface corrodes and prevents wetting.

Stainless Steel

High tin content solders provide the best strength and are used in conjunction with highly reactive fluxes and if necessary hydrochloric acid. The metal must be mechanically cleaned both before soldering for the soldering to be successful and after to prevent subsequent local corrosion.

Aluminium

This metal and its alloys can be soldered using purpose made solders and fluxes, but this is not common and tends to be restricted to production technology.

SILVER SOLDERING

or soldering,

classic use is in the joining of brasses and copper. Note that cadmium free types are recommended for items intended for food handling. The actual method for making a joint is soldered joint is exactly as for brass and is described in the next section.

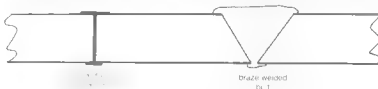
However for silver soldering the flux must be designed for use up to about 600°C. The prevalent flux is known as 'easy flu', which comes in both powder form.

For the filler wire, the silver content can vary between 2 and 85 per cent, but is commonly in the range 22-45 per cent. High contents perform better but get very expensive which is offset by the low volume requirement of capillary joints.

BRAZING AND BRAZE WELDING

Brazing and braze welding use the same filler metal, which has a strength near to that of steel but a much lower melting point.

Brazing, like the soldering technique,



is very local with the flame held close to the work and by careful control of the temperature the filler bridges gaps, corners and V's, that is, it builds up rather than thinly coating surfaces.

Brace welding is quicker than brazing and may result in less distortion because it is done at a lower temperature, however, brazing can produce an almost invisible joint when cleaned up and does not break or distort the joint profile.

Types of Brass Filler Wire

All fillers are primarily brass—a copper-zinc alloy—but have a further significant alloying addition by which they are known. The most common is silicon brass, the others being manganese, nickel and aluminium.

Silicon

When metals are cast directly into their finished shape silicon addition improves fluidity, and refines the crystalline structure making the grains smaller.

Silicon strengthens brass and aids capillary action, so it is a good general purpose wire.

Manganese

This is designed particularly for the welding of cast iron and has good strength bonding characteristics with this metal.

Nickel

Nickel imparts high strength but is the most expensive alloy addition. Typical applications are attaching tool steel tips to machine cutting tools and joining stainless steel.

Aluminium

Aluminium filler is only used for the joining

Types of fluxes	Heat source
silicon manganese nickel	gas electric arc

Types of brazing wire

is reported for aluminium bronzes.

Aluminium Alloys

wire, but in fact simply describes capillary joints made above 900°C, with lower temperatures being made by soldering. Aluminium can be brazed with an aluminium wire, typically with silicon or silicon-copper additions, which melt a little below the melting point of pure aluminium.

Types of Flux

A general purpose borax-based flux obtained in powder form is used with brass filler wires. The exception is aluminium bronze, which requires a unique flux. Proprietary fluxes are available for a range of applications and are not interchangeable—an aluminium brazing flux is not suitable for fusion welding aluminium.

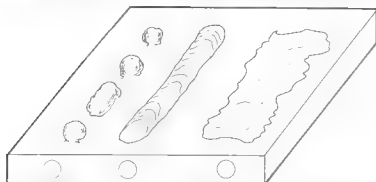
Wires with solder flux coatings or with flux embedded in a serrated surface may be preferred because they enable the joint to be made without active flux.

Heat Source

A blowtorch may provide enough heat to raise smaller pieces but an oxy-acetylene flame is faster and can be used to brace weld. Braze requires a neutral heat source but for

Brazing Technique

Brazing Method Technique



1. Dip brazing

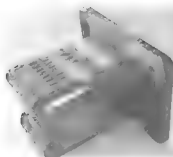
2. Torch brazing

3. Induction brazing
4. Inert gas

Under and overheating
of brass weld beads

Distortion Methods

Cold Churn



As brazed with silver

Mild Steel Iron

Copper Metals

Malleable Irons

3 OXY-ACETYLENE WELDING

Brazing



Braze Welding



varies compared to that of other welding processes and finds use in the ways described.

Uses

Fusion Welding

The flame is directed at the joint edges until each melts and the two flow together. On removal of the heat the material remains united.

This technique is very similar to fusion welding but again the joint strength relies on adhesion rather than fusion.

Silver (Hard) Soldering

A plumber's blowtorch is often adequate but the oxy-acetylene torch is superior for close control on small tasks or for providing



Heat source part of the flame

enough heat on very large ones.

Lead (Soft) Soldering

The oxy acetylene flame is too intense a heat source in all but the most expert of hands but it can still be very useful. Items with a lot of mass or ones designed to lose heat such as car radiators can be readily preheated to speed up the soldering operation and some times are most easily completed with the

Thermal Cutting

By exchanging the welding head for a cutting attachment steels can readily be cut with ease and speed through great thicknesses.

General Heating

Whilst the oxy acetylene torch is designed primarily for welding and cutting it provides an extremely useful source of heat for alternative uses. Some examples are:

1. Heat treatment of items such as chisels.
2. Local heating of metal in order to cause it to bend more easily and at the desired angle.
3. Heating of items to expand them in order that they produce a contraction fit.



Heating a cut and shut angle iron notch

on cooling or perhaps to fracture corroded bonds between components, for example on car exhaust systems.

EQUIPMENT REQUIREMENTS

Oxygen

Oxygen for industrial purposes is always contained in alloy steel cylinders, painted black. B.G.P.A. codes of practice demand that all cylinders meet certain criteria, in practical terms, for welders this means that the cylinder is labelled with the type of gas, and the pressure it is charged to when full at 15°C. This information can also be found stamped onto the cylinder near its neck, along with its tare weight, serial number and so on.

Cylinder Pressure and Contents

In the past decade average cylinder pressures have risen from 175bar to 200bar, and depending on the supplier may soon change to 230bar. This has implications in the use of regular cylinders since older ones are unlikely to be able to cope with these high pressures. At 200bar a standard large cylinder contains 9.660 litres of oxygen.

Oxygen has no smell, taste or colour that would make it easy to detect. Whilst it does not burn it is potentially extremely dangerous. Oxygen has to be present in order for things to burn, but it may not be readily recognized that by increasing the oxygen content of the atmosphere, burning is much more spontaneous and vigorous. This effect is disastrous when, for example, oxygen leaks in a confined space, but of course is put to good use in the controlled situation of an oxy acetylene flame where further oxygen can be added in order to improve combustion.

Oxy-Acetylene Welding



Typical oxy-acetylene welding equipment

Acetylene

Like oxygen, acetylene is supplied in a variety of cylinder sizes, from very small portapacks to the large ones designed for manifold systems. Acetylene is always supplied in steel cylinders, painted maroon, which are shorter and larger in diameter than their oxygen counterparts. The cylinder will again bear a label identifying its contents, and giving pressure, weight, year of issue and so on.

Cylinder Pressure and Contents

Acetylene cannot simply be pressurized like oxygen because it becomes very unstable if



Diagram of a
cylinder with
regulator
and valve



Cross-section through an acetylene cylinder

On Acetylene Welding



Gas Pressure Regulators



Figure 1

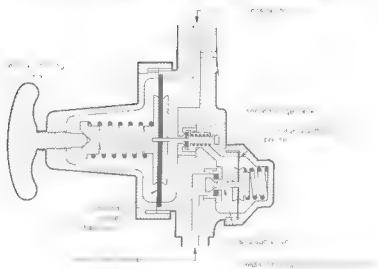
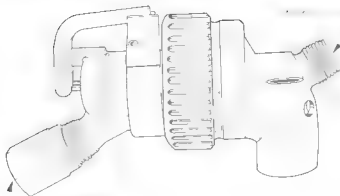
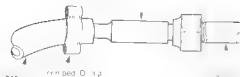


FIG. 10-4-1



Oxy-Acetylene Welding

oxygen to the
pilot orifice



Identifying a hose-check valve

hose

crimped O ring

red acetylene
connection

o-ring

side view



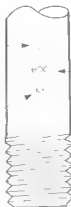
blue oxygen
connection

Identifying a No. 2 torch

Mixing Chamber

The controlled gas supply flows on through the shank and into this unit, where the gases actually mix together. This small, complex unit is made of brass, perhaps chrome plated, and is screwed onto the end of the

oxygen
connection



acetylene
connection

Nozzle

This is made of copper and is screwed into the end of the mixing chamber. Since copper is a fairly soft metal it can be damaged quite easily. The threaded end will not screw on or seal properly if the end is damaged and the flame at the other end will be distorted and flicker as if it suffers damage.

Nozzles are identified with a number, which indicates their consumption of each

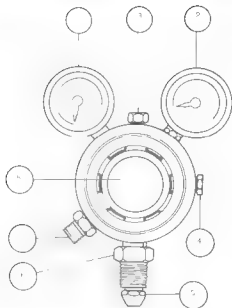
Identifying a No. 2 nozzle

OBTAINING EQUIPMENT

Gas Supply

Gas can be obtained from a supplier. Most should offer competent advice and provide good service. Obtain information on all aspects including the handling, transportation and use of industrial gases.

Regulators



- 1 Outlet pressure gauge
- 2 Cylinder pressure gauge
- 3 Pressure relief valve
- 4 Plug
- 5 Regulator inlet
- 6 Inlet valve
- 7 Regulator outlet
- 8 Adjustable pressure and outlet pressure

4 1/2 x 1/2 x 1/2

will be one made to BS 5741 BS 5650 in the UK, or equivalent, which should be evident on the body of the regulator. It must be capable of handling the pressure of a full cylinder, for oxygen this would be 200 bar.

Flashback Arrestors/Hoses

There are three types of arrestor as discussed above but beyond this there is very little variation. Similarly once the size/length of a hose has been selected then variation in price

support it.

$$\mathbb{I}_d \otimes \sigma_z |c\rangle$$

Many designs of torch are available, with variations in weight and small differences in appearance, but all essentially working in the

MAINTAINING AND REPLACING EQUIPMENT

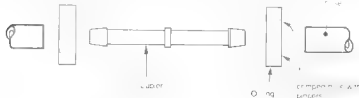
Cylinders must be turned off when not in use and when the cylinder is empty prior to removing the regulator. They should be returned for refill before they are completely exhausted, ideally when the pressure has dropped to about 1 bar. These precautions

we prevent air backflow into the cylinder

No maintenance is necessary or permitted on cylinders. If a cylinder is thought to be unsafe in any way, for example if the gland nut at the neck leaks, then return it to the supplier and accept a replacement.

Regulators, flashback arrestors and torches may each cease to perform correctly after prolonged use or time. These items require expert attention and no attempt should be made to repair them. It is customary to have faulty equipment service exchanged, that is, replaced, with a fully guaranteed, restored item at a lower cost than purchasing a new replacement.

Hoses require a somewhat subjective assessment regarding their safety. If the first layer of canvas shows, as a result of abrasion or burning, or if the hose is heard to "crack" when squeezed tightly through 180 degrees in the hand, or of course if it leaks, then repair or replacement is necessary. Hoses must be repaired properly, by cutting out the suspect length, then re-connecting with a proprietary hose connector, held in place with "tie" pins. Anything less than this is likely to be dangerous. If copper is used in repairing the acetelene line, for example, a chemical compound is formed which in time becomes explosive.



A hose connector and fitting

Similarly the chemical reaction between oxygen under pressure and oil or grease or similar compounds must be avoided, and particular mention of this is made on the cylinder label. The reaction here is a spontaneous explosion. When making gas connections no lubricants, joining compounds or sealers should be used because they are sus-

This is done with a wrench and allowing gas to flow for a second before closing the valve from the cylinder.

ASSEMBLING THE EQUIPMENT

Throughout assembly of the components it will quickly become evident that the system is colour coded: acetylene fittings are all red and oxygen fittings are always blue. The exceptions are the cylinders, which are green and black respectively.

It will also be apparent that there are two types of thread, those on similar fittings will be the same size and pitch, but threads for oxygen are conventionally right hand, and those for acetylene left hand. Left hand threads on gas fittings of any sort indicate that the gas is combustible.

Equipped with 'notched' nuts used on all connections, a feature peculiar to acetylene.



Swirling a cylinder

Gas Cylinders

There are two stages in the preparation of cylinders.

First the plastic cap needs to be broken

Operation of the cylinder in the supply is opened in turn.

before using, so that the acetylene is allowed to settle in the acetylene cylinder.

Regulators

Although heavy and made mainly of metal regulators must be treated as precision instruments. Only then will they function reliably and give long service. New regulators will need to have the protective caps removed from the threaded gas connections. Older ones should be inspected for signs of damage on the mixing surfaces, distortion to the stem, damage to the gauges or indicator needles that do not zero, before reusing. Be particularly cautious with regulators manufactured before 1989, since they may not withstand the cylinder pressure.

The regulator stem is inserted into the cylinder neck, usually hand tightened and then finished off with a gentle hammer tap on the spanner. Consider at this point whether the regulator tools access to the cylinder key knob and if necessary slacken and rotate the regulator to a more convenient position.

Finally, open each cylinder in turn and purge the regulator with gas. This will also drive off enough any dust present.

Flashback Arrestors

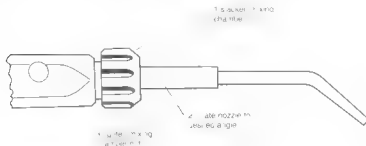
Again remove the dust caps if the arrestor is new, then fit and purge. You will now know if it was put on the right way around!

Hoses

For fitting each hose check valve is at the torch end, and purge. If the hoses are bonded together then split them before fitting so that they will be quite separate when used.

Torch

Fit and purge, then select and insert a nozzle to suit the work in hand. If at this stage the nozzle points at an angle which makes it awkward to use, slacken the mixing chamber connection, rotate the nozzle to the desired angle and retighten the mixing chamber connection.



Topic _____

either faulty or needs further tightening.

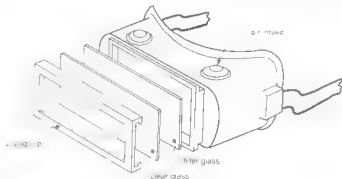
LOCATION OF EQUIPMENT

It is too dangerous to allow the cylinders to stand freely so a method of restraint is nec-

GAS WELDING ACCESSORIES

Meeting Googles

These are absolutely essential in order to see the welding operation clearly without eye strain and without sparks and spatter entering the eyes. They are made of a material which is strong enough to withstand the heat of the welding process and are made of a material which is strong enough to withstand the heat of the welding process. They are made of a material which is strong enough to withstand the heat of the welding process.



because they have a hinged filter glass which flips up to expose a clear glass, but all goggles are made to BS 1342 or equivalent.

Protective Clothing

A number of factors determine what protective clothing is needed. A minor task, done on the bench, undertaken in 'old' clothing may not warrant any further consideration. Protective clothing will, however, be a major consideration if welding overhead while bent over a motor vehicle. In this case a cap would be necessary in addition to the usual overalls and gloves. Cotton clothing without any frays is best for combating welding sparks, which despite the most vigilant efforts will still tend to find their way into socks, up sleeves and down necks. Beware

Flame ignition



kept in a pocket during welding.

Fire Extinguisher

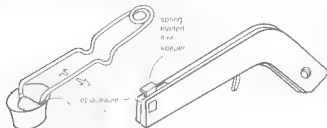
The need to have one of these always to hand during any welding activity must be self-evident. Consideration should, however, be given to the type.

Water is excellent and reduces the likelihood of further ignition but is not a wise choice when working near to electrical equipment.

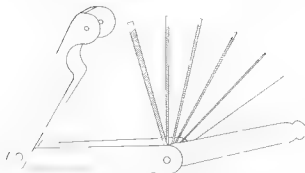
Other possibilities are CO₂, Foam, and BCF, each having its own merits and disadvantages.

Nozzle Reamers

During use the welding flame may become distorted or choked because some spatter has got lodged inside the end of the nozzle. Nozzle reamers are a pack of edged cleaners



Welding



Clamps

Since welding involves holding two or more pieces of metal together and heating them, some sort of clamping system is often necessary both to aid initial assembly and to hold the pieces in place during welding. Of the myriad types of clamp available, C-clamps and more grips will find much use.

PREPARING THE WORK

excess oil, grease, paint, sand or rust. Cleaning with an angle grinder or a pedestal grinder may be necessary if the surface is badly corroded.

The components need to be held together well enough not to move unduly when tacking or welding, and the clamp, grip or whatever is using must be capable of withstanding welding heat. If possible, assemble the whole assembly, that each component helps hold another in place during assembly and so that the appearance of the finished job can be checked.



Use C-clamps and

... ..

See also 1729 Felt, E. H. and W. W. C.

[illegible]
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Selecting the Files

[illegible]
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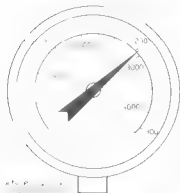
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Lighting the

Turn On Valves

Acetylene Gas Pressure



Pressure

Pressure



Oxygen Gas Pressure

Pressure

Pressure

Pressure

Pressure

Pressure

Pressure

Lighting the Flame

Pressure

Pressure

Oxy-Acetylene Welding



Figure 1. Neutral flame. The inner cone is the primary flame. The outer cone is the secondary flame.

Figure 1

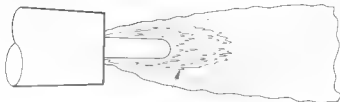


Figure 2. Oxidizing flame. The inner cone is the primary flame.

Figure 2

The oxidizing flame is used for welding of steel and cast iron. It is also used for welding of copper and brass. The oxidizing flame is characterized by a short, intense inner cone and a short, intense outer cone.

The Oxidizing Flame

The oxidizing flame is used for welding of steel and cast iron. It is also used for welding of copper and brass. The oxidizing flame is characterized by a short, intense inner cone and a short, intense outer cone.

Applications of Flame Types

The neutral flame is used for welding of steel and cast iron. It is also used for welding of copper and brass. The neutral flame is characterized by a well-defined inner cone and a larger, more diffuse outer cone.

Dry-Acetylene Welding



Inner cone
Outer cone
Heat-affected zone

Inner cone
Outer cone
Heat-affected zone

400-200-1000

The flame of a dry-acetylene torch is characterized by a sharp, pointed inner cone that is surrounded by a larger, more diffuse outer cone. The inner cone is the most intense part of the flame and is responsible for the high temperatures achieved in dry-acetylene welding. The outer cone is less intense and is responsible for the preheating of the workpiece. The heat-affected zone is the area of the workpiece that is heated by the flame but does not melt. The size of the heat-affected zone is determined by the distance between the torch and the workpiece and the speed of the torch movement.

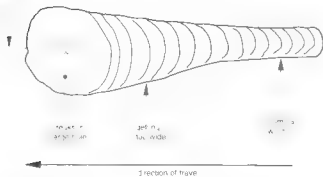
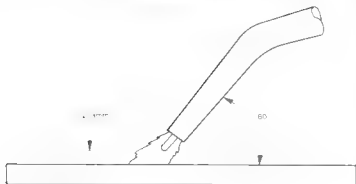
Making a Weld Bead

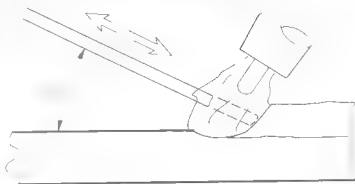
Without Filler

When making a weld bead without filler, the torch is held at a distance from the workpiece that allows the inner cone of the flame to impinge directly on the workpiece. The torch is then moved back and forth in a weaving motion, creating a weld bead that is composed of the metal that has melted and solidified. The width of the weld bead is determined by the distance between the torch and the workpiece and the speed of the torch movement.

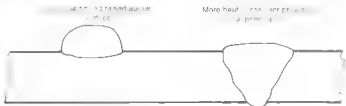
With Filler

When making a weld bead with filler, the torch is held at a distance from the workpiece that allows the inner cone of the flame to impinge on the workpiece. The filler metal is then added to the weld pool, and the torch is moved back and forth in a weaving motion, creating a weld bead that is composed of the metal that has melted and solidified, plus the filler metal.





Welding torch

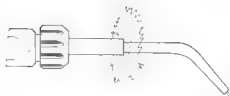


Beads on plate with and without full penetration

Oxy-Acetylene Welding

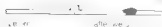
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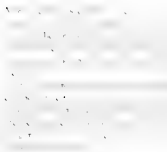
Stitching Two Pieces



45° entrance angle 90° exit

Adjusting the position

Tacking



MAKING GAS WELDED JOINTS

Butt joints



Making a Close Square Butt Joint



Making an Open Square Butt Joint



A T-joint



Flange
on pipe

Welded
web

On Acetylene Winding

by E. J. ...

Outside Corners

MUSCO S. G. & A. B. ...

...

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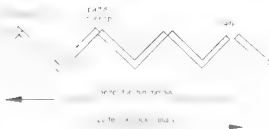
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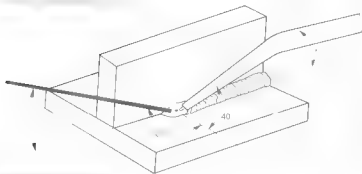
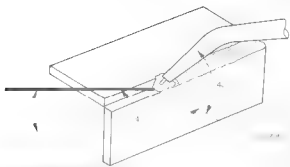
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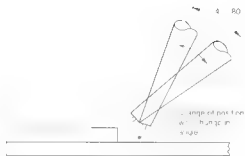
Inside Corners and T-Fillers



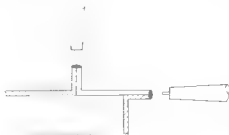


Tap Joints

Oxy Acetylene Welding



Torch angles in position



Torch angles in position

Oxy Acetylene Welding

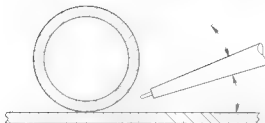


Fig. 1

Gas welding variables

Gas Welding variables

1. Gas pressure

2. Gas flow rate

3. Gas composition

Size of Material

4. Thickness of material

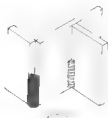
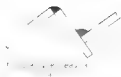
5. Position of material

6. Position of weld

Position of Weld

7. Position of weld

O₂ Acetylene Welding



Notes:

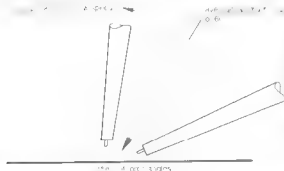
Torch Angles



Speed of Travel



3. Acetylene Welding



Filler Wire Size

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- 2. 1/8 inch
- 3. 3/16 inch
- 4. 1/4 inch
- 5. 5/16 inch
- 6. 3/8 inch
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Technique

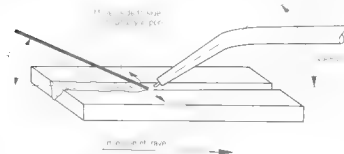
Leftward technique used by a right handed welder. The torch is moved from the right towards the left at the joint. A left handed person would weld towards the right, so the leftward technique essentially means that the flame points in the direction of travel and is preceded by the filler wire.

Welding of metal over 3mm thick can be greatly speeded up by using the 'rightward' technique but the prevalence of arc welding for such thicknesses has outdated this in

Other Factors

OXY ACETYLENE EQUIPMENT - SAFETY DEVICES AND PRECAUTIONS

This section should be read and its contents understood before starting to use the equipment for any purpose whatsoever. It is sent at this point rather than the end of the chapter because it is necessary to know at least the equipment and how to use it before the safety devices it contains can be fully appreciated.



Torch and filler angles for the rightward technique

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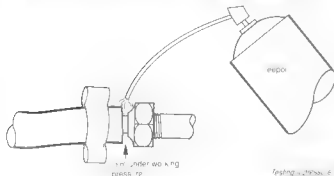
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Testing pressure ...

Coated Metals

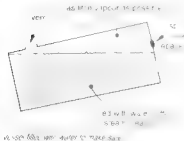
Materials coated with paint, grease, oil, or other foreign matter or with scale or rust should be cleaned before welding. Zinc is a gas-forming element and causes porosity when welded, galvanized steel is an exception. Remove the zinc scale by sanding. Remove the paint by sanding. Use effective fume extraction.

Fuel Gas and Oxygen

Fuel Tanks

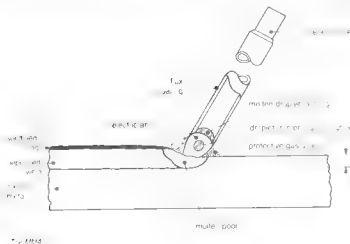
When welding fuel tanks, use the following precautions:

- 1. Ventilate the area.
- 2. Remove all flammable materials.
- 3. Use a fire extinguisher.
- 4. Use a fire blanket.
- 5. Use a fire hose.
- 6. Use a fire alarm.
- 7. Use a fire watch.
- 8. Use a fire drill.
- 9. Use a fire drill.
- 10. Use a fire drill.



4 MANUAL METAL ARC WELDING

Manual metal arc (MMA) welding is the most common welding process in America and in Britain historically has



gap it generates enough heat to melt the electrode and the surface of the metal. The electrode end is propelled by electrical force to the melting metal surface, where it mixes and builds up as the weld bead.

The flux coating on the end of the rod also melts and protects the metal whilst it is molten. It solidifies to become a slag and continues to protect the weld metal as it

- 8. Welding return
- 9. Welding cart

Source of Energy

Most welding is done by using an electric arc. A 240 V AC electric supply is used in DIY work. A phase supply is used in professional work.

Other welding methods involve a gas flame, where a gas is used to heat the metal.

THE WELDING CIRCUIT

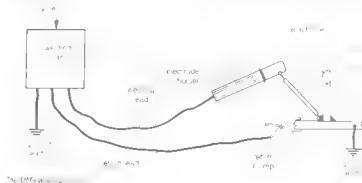
The following components are the essential features of the manual metal arc welding circuit:

Source of energy

Welding Set

The welding set

The welding set



Output Voltage

1. Connect the voltmeter across the electrode lead terminal and the work terminal, which will read 50V.

2. Turn the output control knob to the 80V position.

3. Turn the output control knob to the 90V position.

4. Turn the output control knob to the 100V position.

5. Turn the output control knob to the 110V position.

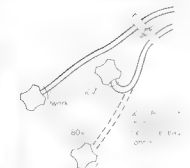
6. Turn the output control knob to the 120V position.

Output Current



Fig. 1-1

Fig. 1-2

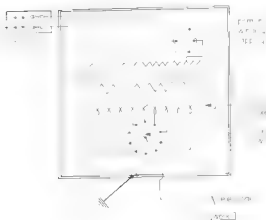


Open circuit voltage is 120V.



Fig. 1-3
Fig. 1-4
Fig. 1-5

Manual Metal Arc Welding



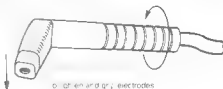
Electrode Holders

Manual Metal Arc Welding

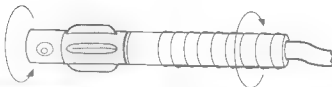


DICTIONARY

Stranded end of a welding lead



o. of an and pr. electrodes


$$A_1 \otimes A_2 \otimes \cdots \otimes A_n \cong A_1 \otimes A_2 \otimes \cdots \otimes A_n$$

References

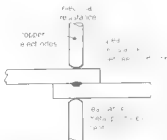
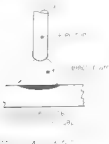
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electrode core
granular coating

granular coating

identifying electrodes



numbered on the coating and/or a series of figures which indicates its classification. In the UK, E4631N.B.4H5 is a particular category in BS EN499:1995 whilst '6013' is a very common American coding for general purpose, positional rods.

The Electric Arc

The two main ways of using electricity to

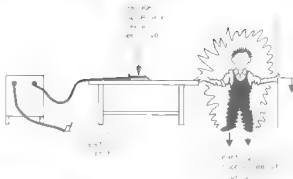
produce heat for welding are from electrical

There are in all these processes the visible evidence of electricity jumping a gap between the end of an electrode and the material being welded. More importantly, great heat is produced as the current overcomes the electrical resistance of the gap.

The heat generated is at approximately 4,000 °C but will vary between electrodes

When Males Are Standing

OBTAINING EQUIPMENT



accessories thrown in, perhaps. The items can also be purchased individually. The same vendor will also supply electrodes, acting as an agent for one of the many large electrode manufacturing companies. Very small quantities can probably be obtained from DIY stores, but at a high unit cost.

MAINTAINING/REPLACING EQUIPMENT

Welding Plant

Transformers need practically no maintenance and rarely break down because there are no moving parts. Oil cooled types will need the level checked roughly every two years, but could well go for twenty years without needing any topping up. Transformer oil should be used, of course, which means even if it is electrically non-conductive.

Rectifiers are not immersed in oil and the only maintenance necessary is to take the side rear panels off and remove the dust build up periodically by blowing through dry

lie expectancy of a rectifier that is, the length of time that 'spares' can be expected to be readily obtainable is seven years. This is one of the factors influencing the choice between repair of or replacement of the set.

Generators need lubrication of moving parts and renewal of brushes as necessary, along with a supply of diesel.

Welding Cables

Cables for welding are sized in terms of their current carrying capacity, and to avoid overheating they will need to match the maximum output of the welding set.

The protective rubber coating must be checked regularly in order to prevent electrocution or electrical damage to other equipment and it must be ensured that spatter or hot metal does not burn through the insula-

After prolonged use, flexing near to either the welding set connection, or particularly the electrode holder, causes the wire strands to fracture, reducing the effectiveness of the conductor, eventually the cable may even



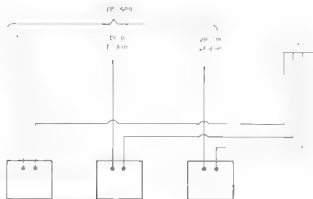
in the welding set and the work, the cable can be lengthened, but this must be with caution. Making a conductor twice also doubles the resistance, which in doubles the heating effect. If the cable is used at more than half its capacity, should not simply be made longer to get in cross section. This will reduce heating effect and loss of power at the proprietary cable connectors for

INSTALLATION AND ASSEMBLY

Electrical Supply - Primary Connections

If a portable 415V set is supplied from a 33kV plant, then placed in a dry, situation, it is ready for use. In industrial situations the fitting of an appropriate plug is governed by company policy and is done by a suitably qualified person.

FIGURE 1



Welding Circuit - Secondary Connections

Once the welding set is safely installed then the welding operator can make the following connections, as necessary:

1. Electrode holder to welding lead. The bare end of the lead is invariably equipped in position with a number of Allen screws. Remove the holder sheath and slip over it and expose the lead end clamp in place and secure the holder sheath back over the case fully ensuring no bare metal is exposed.

2. Welding set to welding lead terminals. Most welding sets which are pushed into the welding set terminals are fitted in the same manner as electrode holders. Lay the connections are placed over a threaded terminal on the welder and held in place with a nut. The lead is secured to the lug by soldering (see Fig. 1.10).

3. Return lead connections. These will be made in the same manner as the welding lead connections but a device needs to be fitted at the work end that enables it to be attached to and removed from the work quickly (see Fig. 1.11).

200 amperes. Where all work can be done on a bench then a soldered lug fitting to the semi-permanently to the bench is a cheaper alternative.

4. Establishing an earth. An effective earth should be attached to the work or bench in addition to the return lead. Often the most practical source of earth bonding, is the steel frame of the building, but again if in doubt prove in character to sort it out.

MMA WELDING ACCESSORIES

With a supply of electrodes the equipment is

Welding Screens,

Face screens are necessary to protect the face from exposure to harmful radiation emitted by the arc. They need to be light and robust, must cover the full face, and carry a filter glass through which the bright arc can be observed.

There are two types of screen, one which is hand held. The former gives high visibility, which is essential in MIG welding, for example. When MMA welding, the free hand may be used to hold a piece of metal in place for tacking, or to hold a corner or corner for stability. Hand held screens are less aesthetically pleasing and provide a receptacle for the electrode holder when it contains a 'live' electrode that is not being used.

All screens contain a filter glass which reduces the intense light of the arc so that it and the weld pool can be viewed comfortably. The glasses are categorized in BS 679 with higher numbers for darker ones to suit the increasing light emitted at high amper-



Head shields for arc welding

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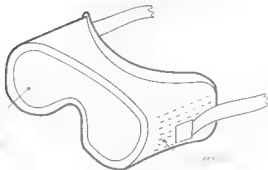
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Chipping Tools

Chipping Hammers

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made specifically



Welding torch nozzle



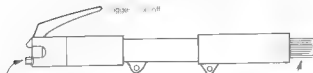


Figure 1.1.1

Welding

Protective Clothing

The primary concern when welding is not protecting street clothes but protecting the body from the radiation and heat generated by the arc. Ultra violet radiation burns any exposed skin in the same way as very intense sunlight. This exposure may not be direct but polished metal or white walls must also be avoided. The short term effect can be deep painful burning, which, like sunburn, may not be fully appreciated until it is too late. In the long term exposure to UV radiation can cause skin cancer.

For most work, but the additional protection of a leather apron is highly recommended.

Protective Footwear

Top of the boot a welder is instantly recognizable by the number of holes in his sock. In extreme cases, such as when heavy arc gas cutting, leather spats are available to protect the lower leg from spatter burning.

Other Accessories

The same accessories as those required for gas welding will be necessary when assembling metal by any process. MMA tasks tend to be heavier and may therefore require more robust clamps, gas hammers and so on.

USING ARC WELDING EQUIPMENT SAFELY

When using arc welding equipment, the following safety precautions should be observed:

1. Always wear appropriate protective clothing and equipment.
2. Always use proper welding technique.
3. Always use proper ventilation.
4. Always use proper grounding.
5. Always use proper electrical safety.
6. Always use proper fire safety.
7. Always use proper personal safety.
8. Always use proper equipment safety.
9. Always use proper work area safety.
10. Always use proper safety procedures.



plus per 38
115
115
115



mask to cape



One dealing with electricity should exercise caution and this must include the welder, who has perhaps 300amps running through the centre of his hand!

Electrocution occurs in one of two ways - completing or forming part of the circuit or by 'carrying' the circuit. The danger usually arises when the welding set is turned on and described as being 'live', but before the welder is struck. Once the welding arc is under

are rarely being carried through the

Assuming that the welder is properly protected by his clothing and that is, the

Radiation

Radiated Heat





The spectrum

Visible Light

The light emitted from the arc is so intense that it cannot be viewed without a filter. These are categorized in Britain in BS 2795 as discussed under Protective Clothing in

Ultra-Violet

Light on this wavelength is filtered out as it passes through any piece of glass. The welding filter glass is coloured primarily in order to reduce the visible light passing through it, but it also filters out ultra violet radiation as well.

'Arc Eye'

If the arc is viewed with the naked eye, even then there are both short and longer term effects. Initially the iris contracts to compensate for the bright light to which it is momentarily exposed. The operator may see bright lights or stars, but the view is basically one of darkness, until normal vision is gradually restored over a period of 10 to 20 seconds.

Welding may now continue, without any discomfort or further thought, until some time later the eyes feel extremely painful and as if they are filled with sand. This condition develops about 4-6 hours after the exposure which caused it, often out of working hours.

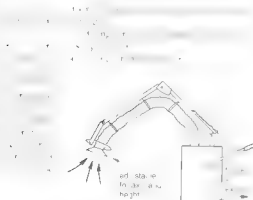
after from his sleep.

The arc unit of paint suffered varies with

1. The current being used
2. How close the arc is observed (over 30m away is 'safe')
3. How long and how many times the eye is exposed to the arc
4. The angle at which light enters the eye (entry from the side seems to be worse)

To prove that arc eye is occurring, the welder must adopt safe working practices, that is, he should always ensure that his eyes are protected by the screen before striking an arc. Due to the very manual nature of the process it is quite easy to strike an accidental blow.

Operators working with or near to welders are particularly susceptible, because they are not a control of, or perhaps not prepared for, welding. All welding areas must have suitable and adequate screening, and are best painted in dark, non reflective colours. Operators assisting the welder must also have a welding screen, or look away at 180 degrees to the arc. Viewing the arc through closed eyelids is not possible and asking for trouble.



Adjust torch for distance



Heat



picking up metal is learned.

Burns are not only painful in themselves, but the heat of the arc on the burns then makes further welding very uncomfortable.

Dealing with Burns

It is important to act very quickly to treat

extent of turning the flame off and putting the electrode holder down safely. Act quickly but do not cause any further accidents!

2. Run cold water over the burned area. This will bring almost total relief from the pain but equally importantly will prevent the burn spreading and becoming much worse than it need be.

3. Continue to keep the burned area under cold water for about 10 minutes, or until the burn can be removed from the water without warming up and becoming painful again.

4. Cover with a clean dressing and a gauntlet before continuing welding. Do not apply

5. Of course medical aid should be sought if the burn is extensive.

Heat Exhaustion

Welders can suffer from heat and dehydration in the same way as foundry workers. When engaged in heavy work on a hot day or in a foundry, or in a confined space and with a minimum dress requirement, care should be taken not to become too exhausted.

Slag

Much like burns, one moment of carelessness is rewarded with a long period of pain.

Wear chipping goggles!

PREPARING TO WELD

Preparing the Material

Chemical MMA welding has a high tolerance for rust, paint, oxide and so on, because the fluxing action of the electrode coating is very effective. For high quality welds to be produced, however, or where these contaminants prove to make the weld porous or brittle, the metal must be degreased and ground.

MMA welding is generally applied to thicker metals and this may demand suitable edge preparation in order to weld controlably through the full thickness.

Setting up for Welding

The following points will need to be checked before welding can commence:

1. Electrode type
2. Electrode diameter
3. Type of welding plant
4. Electrode polarity
5. Voltage setting on welder
6. Current setting on welder
7. The working earth is in place
8. The return lead connection is made
9. The area is screened as necessary
10. The welding screen with suitable filter is available
11. The chipping hammer and wire brush
12. The components are set up and/or clamped together
13. The components are set up on bench



FIGURE 1-10

Electrical Safety

Welding is a hazardous activity. It involves the use of electricity, heat, and molten metal. Therefore, it is essential to follow safety procedures to avoid accidents and injuries. Some of the safety measures to be followed are:

1. Use proper electrical safety procedures.

2. Use proper safety equipment, such as protective clothing, gloves, and eye protection.

Exercises for Chapter 1

1. Draw the following welds:



2. Draw the following welds:



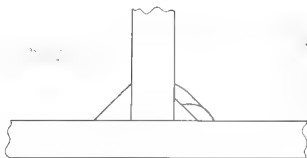
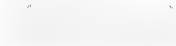
Type C Working Plant



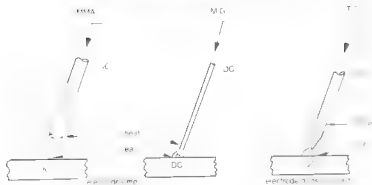
Voltage Setting



Electrode Polarity



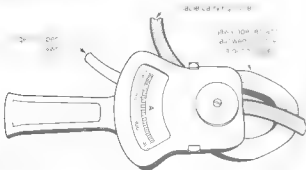
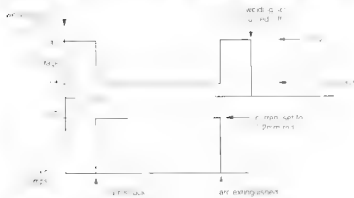
Welding Process

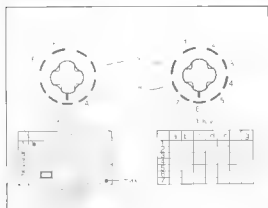
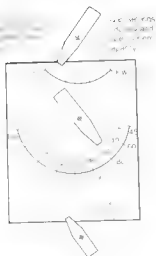


Manual Metal Arc Welding

Current Setting

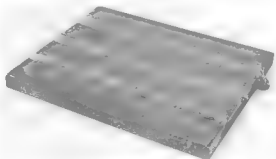
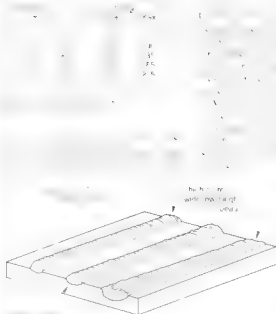
When setting the current, the operator should refer to the current setting chart for the electrode diameter and the type of joint. The current should be set within the recommended range to ensure a good weld.





□

Manual Metal Arc Welding



MAKING A WELD BEAD

Striking an Arc

The arc is initiated by bringing the electrode end into contact with the parent metal so that current starts to flow through the circuit. The electrode is then raised above the parent surface about 3–4mm and current flows across the gap creating an electric arc with intense heat and light.

The easiest way of striking an arc, with consistent success, is to draw the electrode end through an arc, scraping the plate surface at the lowest point and rising finally to produce the arc length.

The alternative is to tap the electrode end directly onto the surface and lift it up. Whilst this method can be successful and accurate it is very susceptible to sticking, which in the first method is prevented by the movement along the surface.

If the electrode does stick, it should immediately be firmly moved to side to release it, but how this is done will occur at this moment to respond quickly results in the resistance heating, which causes rather than on as free. If it fails then the situation is made safe by the welder off, releasing the holder to avoid then removing the electrode.

The sequence when striking an

1. Place the electrode end above the starting point.
2. Keeping the electrode steady, screen in front of the face.
3. Strike the arc, and in the light, also re-locate the starting point.

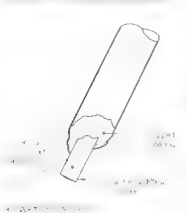
Difficulties will be experienced at striking an arc at a precise point. This is developed because weld beads



Striking an arc

Common Difficulties in Stick Arc Welding

Stick arc welding is a common method of joining metal. It is a manual process that requires skill and practice. One of the most common difficulties in stick arc welding is starting the arc. This can be caused by a number of factors, including a dirty electrode, a weak power source, or a lack of skill. Once the arc is started, there are several other common difficulties that can occur, such as a wandering arc, a lack of fusion, or a poor weld bead. These difficulties can be avoided by following proper technique and using the right equipment.

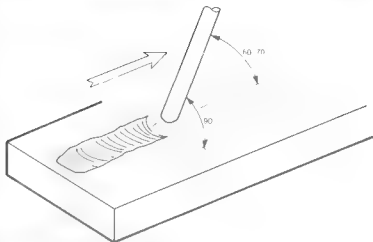


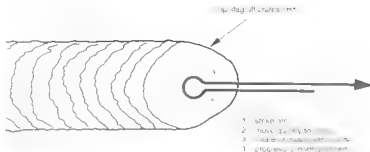
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Starting a Bead

Starting a bead is the first step in stick arc welding. It is a critical step that requires skill and practice. There are several factors that can affect the ability to start a bead, including the type of electrode, the power source, and the skill of the welder. Once the bead is started, it is important to maintain a consistent arc and to move the electrode at a steady pace to create a strong weld.

Continuing a Bead





Finishing Off the Bead

If the arc is simply extinguished at the end of the joint then it leaves a hollow crater which weakens the weld and which may crack as it strikes on cooling. To fill in the crater

- 1 Weld up to the point where the leading edge of the pool is at the end of the joint
- 2 Pause for about 2 seconds to fill in
- 3 Weld back in the opposite direction for about 3mm without changing the angle of the electrode
- 4 Withdraw the electrode promptly in the prescribed direction

WELD PADDING

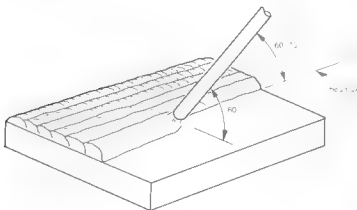
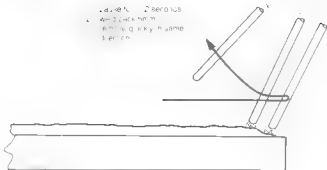
dimensions of 1.5 × 100 × 10 mm, but the bigger the better. The bead should be continuous, extend over the full length, and on completion be deslashed and wire brushed.

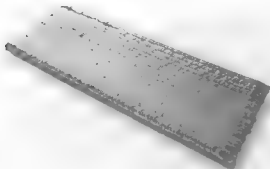
The second bead is not placed randomly on the plate but directed at the toe of the previous one, that is, the edge of the weld. The slope of the electrode is still 60 degrees but the tilt (the transverse angle) is now also 60 degrees, rather than the 90 degrees used for the first bead.

The effect of welding in this manner is that half the new bead covers the first one, whilst the remainder laps over new plate. After a number of passes have been made in this way, displacing between each, the plate thickness will have increased by about 3 mm.

Manual Metal Arc Welding

- 1. draw the electrode back
- 2. zero the electrode
- 3. draw the electrode back
- 4. draw the electrode back
- 5. draw the electrode back
- 6. draw the electrode back
- 7. draw the electrode back
- 8. draw the electrode back
- 9. draw the electrode back
- 10. draw the electrode back





the commencement of each bead. As the plate warms up the beads will become progressively wider and flatter as a result of welding intensively in one area. The aim is for the surface of the weld pad of overlapping weld beads to be as flat as possible so that machining the surface would require minimum metal removal to obtain a fault free, finished surface.

Practical Applications of Paddling

This technique is useful for reclaiming worn surfaces, either with standard electrodes or with purpose made hard surfacing electrodes for improved wear resistance. If the wear has been caused by corrosion then corrosion resistant alloy electrodes can be deposited to extend the working life.

In either case a suitable weld surface might be used to extend the anticipated life of a new component, often with the strength

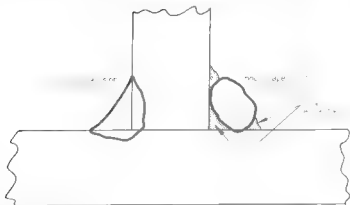
MAKING WELDED JOINTS

Most joints encountered in MMAW are fillet joints, where the weld is placed in a 90 degree corner, without any gap. joints are less common and more difficult to weld.

An edge meeting a surface presents difficulty in gas welding, but MMAW is much less sensitive to this sort of variation. Dissimilar thicknesses are not a problem either, provided that the thinner piece, or the one receiving heat, is not melted uncontrollably. In all welded assemblies the items need arranged in position, probably held by clamps and tacked.

Tacking

The size and number of tacks needs to be learned with experience. Each should be cast from long and they should get the



ring so that the tack can blend in rather than build up in a 'blob' under the electrode end. It helps further if the electrode is one size smaller than that to be used on the job and the current is set 20 per cent too high and again, blend in.

All tacks should be welded through and

Cracks usually tack crack because they accommodate the shrinkage that takes place on cooling. This is most likely when under high restraint. In this case stresses with a higher strength ductile

T Fillet Joints



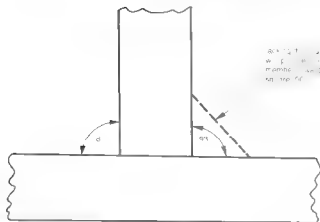


Fig. 1.1. Butt joint in a T-joint.

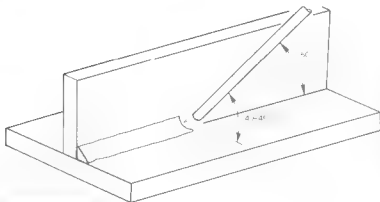
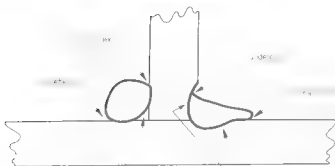


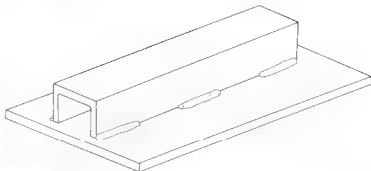
Fig. 1.2.

Manual Metal Arc Welding



Size and Quantity of Welding

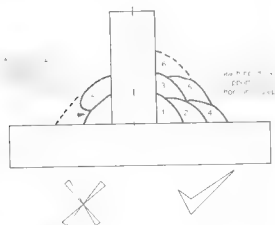
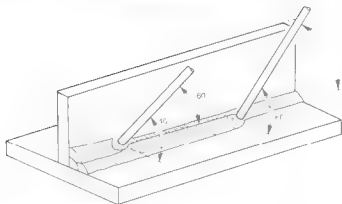
Manual Metal Arc Welding

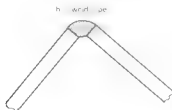
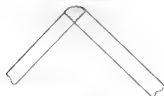
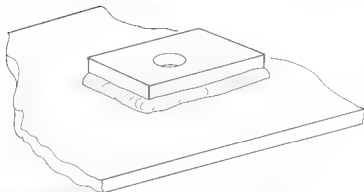


slag beads between

Outside Corner Joints

A "lose" corner joint is one where the plates work at a gap. If full strength is needed then both edges are fully exposed





Butt joints

Butt joints are the most common type of joint used in welding. They are formed by joining two pieces of metal together by welding the ends of the pieces.

required, and the point may be close chamfered.

If plates are butted together, without and a single pass is made along the edge then the weld will not penetrate the full thickness. The strength may

angle iron together to produce the work of a workbench, but the tensile will be well below that of plain iron either leaving a gap or by running a groove on both sides the strength is much increased.

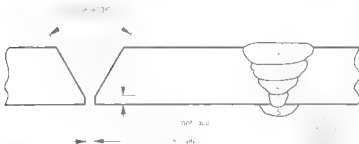
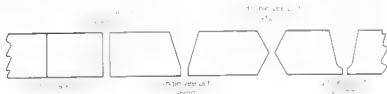
For metal thicker than 6mm fully

from one side, the edges need to be beveled at 30-35 degrees, to form an angle of 60-70 degrees when planed. This can be done with gas cutting either by hand or with machine or mechanically with pedestal grinders or nibblers to produce chamfers.

Finally the leading edge of the remaining metal forms a root face, see

Single V Butt Joints

Single V butt joints are more



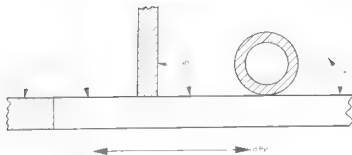


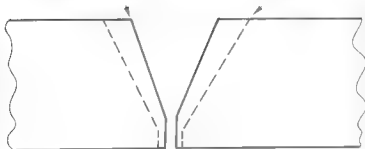
Fig. 1.1. Welding direction.

Root Run



Fig. 1.2

Root Step-Steers
sl



Effect of profile on ease of penetration

Manual Metal Arc Welding



Diagram of a butt joint weld.

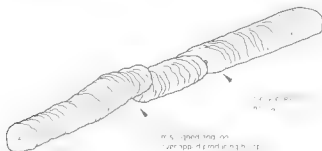
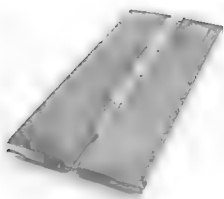
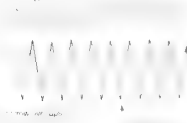
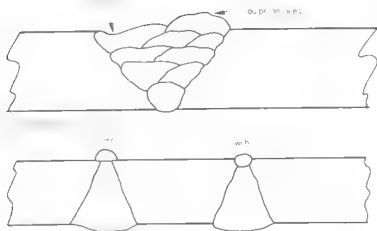


Diagram of a pipe weld.

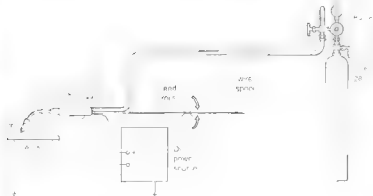
f. If ring up the N

Dealing with Fairies





5 MIG WELDING



The MIG welding circuit

EQUIPMENT REQUIREMENTS FOR MIG WELDING

There are three basic pieces of equipment required for MIG welding:

1. Power source
2. Wire feed unit
3. Torch

Power Source

There are two types of power sources used for MIG welding: constant speed and constant voltage. Constant speed power sources are used for gas metal arc welding (GMAW) and constant voltage power sources are used for gas tungsten arc welding (GTAW).

Constant speed power sources are designed to maintain a constant wire feed speed regardless of the arc length.

Constant voltage power sources are designed to maintain a constant voltage regardless of the arc length.

Constant speed power sources are used for MIG welding of thin materials and constant voltage power sources are used for MIG welding of thick materials.

Constant speed power sources are used for MIG welding of thin materials and constant voltage power sources are used for MIG welding of thick materials.



An industrial MIG welding situation with wire feed unit mounted on an overhead boom

The Wedding and Assembly

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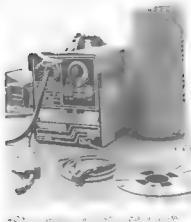


The Weaving Torch

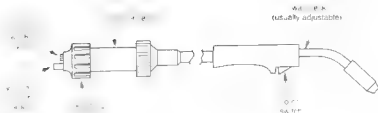
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MIG Welding Tips

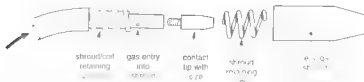
MIG Welding Tips



MIG Welding



The MIG welding lead assembly



The MIG welding torch

The tip is surrounded by a welding shroud, whose function is to direct gas towards the weld pool. The diameter varies with torch

demand for shielding gas. They are made of copper to withstand heat and general wear

Spool of Wire

Spool sizes are 1kg, 2kg, 5kg, and 15kg, the

and they tend to be made to a high specification in order to be suitable for a range of materials. Thus wires are available for carbon

arc and its alloys and so on.

There are four main sizes: 0.6mm, 0.8mm, 1.0mm and 1.2mm. The wires are all for but the range of leg lengths that can be produced is great, ranging from 2mm with 0.6mm wire to 10.0mm with a 1.2mm one.

The Wire Feed Unit

The wire feed unit is a device that controls the flow of wire from the spool to the torch. It is usually mounted on the power source and has a control knob to adjust the wire feed speed. The unit also has a pressure gauge to monitor the gas flow and a warning light to indicate when the wire is running out.

MIG Welding

Electrode	Wire size	R ₁ H		Wire feed speed ft./min.	Travel inches	Amperes	Voltage
		Carbon	Argon				
E6010	1/16"	10	10	32	9	20	18
	3/32"	10	10	40	11	25	20
	1/8"	10	10	50	14	30	22
	5/32"	10	10	75	20	40	26
	3/16"	10	10	100	28	50	30
E6011	1/16"	10	10	32	9	20	18
	3/32"	10	10	40	11	25	20
	1/8"	10	10	50	14	30	22
	5/32"	10	10	75	20	40	26
	3/16"	10	10	100	28	50	30



Shielding Gas

A shielding gas is supplied to the welding area to displace the air and provide a controlled atmosphere. Only aluminum and nickel and their alloys are best welded with a totally inert gas. All other metals use a mixture of gases, typically argon based but with varying additions of carbon dioxide, oxygen, helium or hydrogen.

Disposable or small rechargeable canisters are expensive to run as stated earlier. Industrial cylinders vary from 2,500 lbs.

MAINTAINING/REPLACING EQUIPMENT

Welding Plant

Modern welding centers are very reliable and with the exception of a cooling fan have no moving parts. The only maintenance possible or necessary is periodic removal of dust and metal particle build-up inside machine. This is done with compressed air. Be sure that the air is dry and clean.

Welding Lead Assembly

Excess wear in the liner produces erratic feeding of the wire, which indicates need for replacement. To remove it, extract the wire from the liner, disconnect the electro-connector at the machine and withdraw the liner from the connector.

The liner is either a helically coiled flexible metal tube or a Teflon tube, the latter has a smoother linc but unlike the metal tube does not clog with etched wire particles, especially with soft aluminium wire.

Welding Torch

The welding tip wears rapidly and often causes

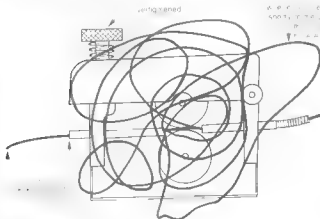
Shroud

These are a sliding fit over a full coil and require replacement because they are dented or worn to direct gas properly. Naturally, the coil may cease to grip shroud.

ASSEMBLING THE EQUIPMENT

Loading the Spool

The spool is loaded ensuring that the peg in the wire feed unit is located in a s drive groove. It must be put on the right up side and so that the wire feeds directly



The wire feed rolls with entangled wire

es to start the type off on this stage and the pass slipped over the capillary and screw home.

PREPARING TO WELD

The wire type and size are selected next and in the gas type and flow set at

Setting the Gas Flow

Flow of 2 per cent oxygen and between

If gas (C) has increased the heat penetration rate are but also produces more sp. The per cent is recommended for steel 50 to 70 and above this thickness 70 per cent. A constant shielding gas available

wire produces good welds through the range in diameters.

The amount of gas needed to protect the weld pool is determined by the shield diameter, and increase as welding gets heavier. Table 1, 2, 3 are only used if the flow of oxygen pressure can be measured.

The wire is drawn into the spool and pushed through the larger wire feed rolls which are part of the feed unit. One roll is a self-faced wheel the other has a groove equal to the wire diameter. Rolls type 1 are a good design, wire wire, roller roller, roller and to spin or 100 mm and 100 mm. The roll must be mounted correctly in order to make use of the correct groove.

After this the wire end is fed into the wire guide tube, on through the opening and into the wire connection guide tube.

It spins in the groove.

After it is set in the groove, the pressure is adjusted. The wire is most important wire well enough to get the speed but if the wire is prevented from wire for a reason mechanical, the wire is not spun on the wire. To correct this, the wire feed wheel is set in the wire, the wire is set in the reel assembly and the wire is set in the box. If this happens the wire

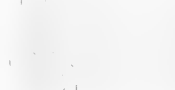


Table 1. Gas flow rate (liters per hour) for different wire diameters.

Wire diameter (mm)	Gas flow rate (liters per hour)
2	10
4	40
6	70
8	90
10	100

Table 2. Gas flow rate (liters per hour) for different wire diameters.

Wire diameter (mm)	Gas flow rate (liters per hour)
2	10
4	40
6	70
8	90
10	100

Table 3. Gas flow rate (liters per hour) for different wire diameters.

Wire diameter (mm)	Gas flow rate (liters per hour)
2	10
4	40
6	70
8	90
10	100

Table 4. Gas flow rate (liters per hour) for different wire diameters.

Wire diameter (mm)	Gas flow rate (liters per hour)
2	10
4	40
6	70
8	90
10	100

Setting the Electrical Conditions

The three main electrical variables are

1. Arc voltage, which controls the type of metal transfer, arc length and weld profile
2. Wire feed speed, which controls the current as well, one knob turning each up, down, and determines the weld size
3. Inductance, which determines the rate of the current rise through the wire

Obtaining satisfactory welding conditions requires careful balancing of all three parameters, and changing any one will have an effect on the other two, which may then also require adjustment to produce a stable arc. The approximate voltage should be set

The two distinct ways in which the wire melts and transfers to the weld pool are known as dip transfer and spray transfer. The mode of transfer is determined by a combination of voltage and current set for a particular wire. For a given wire size dip transfer is obtained at low current/voltage settings, whilst, providing the welder has sufficient capacity, typically 200A or more, spray transfer is obtained at high voltage/current levels.

Initially the voltage is set at roughly the right level to provide the transfer required, and checked with the voltmeter on the machine, press the volt test button or the torch trigger, or by guesswork based on experience.

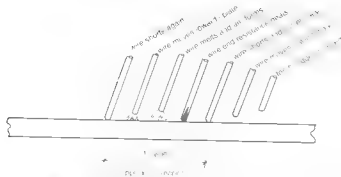
DIP TRANSFER

Welding conditions for dip and spray transfer

1. The wire advances to touch the plate and complete the circuit
2. The wire heats due to the high current passing through it
3. The end melts and transfers to the metal
4. An arc is established
5. The wire advances and touches the plate

This process is known as dip transfer because the wire keeps dipping in the pool. Although it appears to be constant, the arc exists for only part of the time, with the wire "short circuiting" the rest of the time. It is a fairly "coarse" method of welding, good for thin metal and welding vertically and over

Effect of inductance



the period it is short circuiting, the wire will melt so rapidly that it would explode out of the arc, rather like an electrical fuse blowing, producing much spatter and very little weld metal. If the current rise is too slow then the wire will stub or freeze in the weld pool.

Control of the current rise (heating effect) is ensured by having an appropriate inductance in the circuit. On smaller machines this is fixed, whilst larger ones may offer a choice of two or three settings. These are rarely labeled but older machines may identify a choke.

When the inductance is set too low, the wire will melt too rapidly and the arc will be too hot, producing a positive or 'work lead' effect.



4.5 increasing inductance

Identifying inductance settings

1. Producing a steady arc. The arc frequency and due to the longer arc short circuits. The arc produces less spatter than lower inductance.

2. A higher short circuit inductance setting and spatter and a more stable weld, but it will be too hot.

3. High inductance setting on thick metal, which is unfortunately more susceptible to shorting and positional welding.

Setting Up Dip Transfer

1. Producing a steady arc.
2. Supplying the right amount of wire.

3. Supplying the right amount of heat for adequate fusion

MIG welding is notorious for being able to satisfy the first requirement, and by adjusting the welding speed the second one also, but badly failing to produce fully fused weld

Whilst approximate voltage/wire feed speeds can be recommended the final settings can only be established by producing a range of welds, ideally in a simulated situation, and arriving at optimum conditions through trial and error.

Arc Voltage Adjustment

With very low settings the arc is so short that the wire may stub pushing the hand back, and be very erratic. Increase in voltage lengthens the arc to the point where it becomes stable, but further increase results in the wire end melting in a ball, this globule eventually transferring to the pool. This is occasionally useful and is known as globular transfer. As the voltage is increased the high narrow weld profile progressively gets wider and flatter.

Wire Feed Speed

The speed at which the wire is fed determines the size of weld, that is, the amount of metal deposited. A larger weld is produced

shorter the arc because the voltage/current balance has been altered. It is possible to change either the wire speed or the voltage a little without changing the other, but if the arc is lengthened significantly then an accompanying increase in voltage is necessary to keep the arc stable whilst making the larger weld.

Smaller welds are of course made by turning the wire speed down, and re-balancing the voltage as necessary.

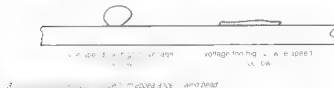
The degree to which the wire speed/voltage balance can be raised or lowered is limited by the stability of the arc. Settings which are simply too low for the wire produce a weak arc that tases poorly. Very high settings produce an arc that is overly forceful, agitating and pushing the weld metal out of place.

Changes are required to a smaller and larger diameter wire respectively, so that they operate at current densities that are stable.

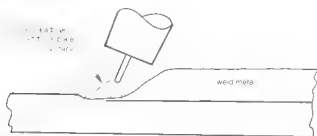
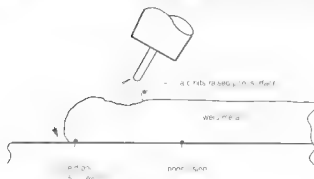
Welding Speed

The weld size can be varied by changing the speed of travel but again there are limitations. Very large weld beads can be made in a single pass and may appear to be good and

ready to be far less effective than supposed. In a destructive test, or if failing in service, the joint would have a fracture surface exhibiting lack of fusion in the root and the



MIG Welding



it course exceed the capacity of the welder, or a 1.2mm wire may already be in use, in which case a number of smaller runs should be used in preference to a single large one.

The difficulty arises in recognizing that arc of fusion is occurring, so professional training and quality control are essential to ensure sound welds.

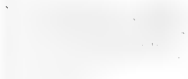
SPRAY TRANSFER

With voltages above 25V the wire melts differently. Once the arc is established, it is permanent, that is, the wire does not dip into the pool, and short circuit. This mode of transfer is therefore unaffected by inductance setting.

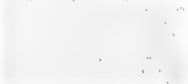
At high voltage wire feed levels fine motion droplets form at the end of the wire

arc is continuous this method is suited to making large well fused welds on thick metal, but is too hot for thin or positional work.

Setting Up for Spray Transfer



Voltage - Wire Speed Setting



after initial arcing. The arc is very intense; a particular attention should be paid to protection against arc burn eye.

FOR BOTH TYPES OF TRANSFER

Initially the voltage is set roughly to provide the type of transfer required and at a level suited to the wire diameter: larger wires require higher voltages.

It is important to set the wire 'high', a slowly reducing tip, because if it is low (and voltage high) the wire will melt back onto the tip instantly. One second of attempted welding is then followed by a period of 3-5 minutes of 'maintenance'. The fused tip eventually means the tip has to be replaced, and if a torch switch was not released quickly then the wire may have burst out of the wire feed reel mechanism. Both situations are frustrating, testing the welder's patience and wasting time.

It will be apparent that the arc length can be changed by an alteration to either the voltage or the wire feed. Which one needs adjusting?

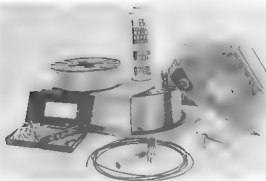


MIG Welding



FNA, PREPARATION

MAKING A WELD BEAD



at about 80 degrees to ensure maximum use of the gas shielding. A too acute angle causes

1. Ingress of air into the shielding gas, drawn in by the moving gas. This can also happen if the gas flow is set too high and results in scummy welds and porosity, often visible on the surface.

tivity to changes in distance or slightly work movement of the torch.

The Self-Adjusting Arc

It will be found that if the contact tip height and distance to the length and stability of the



Effect of MIG torch angles

MIG Welding

difficult than MMA to

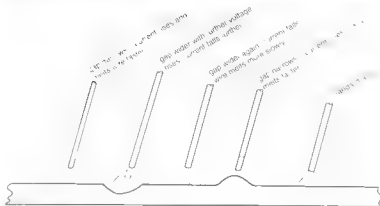
the arc is illustrated

quickly until the arc length ready

Finishing a Weld Bead

MAKING

Tackling



4 (continued)

2. Closing the gas cylinder valve.
3. Turning the regulator pressure adjust

MAKING WELDED JOINTS

Much of the skill in making good joints is in setting the welder correctly and it is useful to have a similar joint on which to practise and evolve the best welding conditions before committing to the actual task. This practice is essential until the operator has both experience and familiarity with the machine.

Tacking

Tacking with MIG is very much easier than with either gas or MMA welders. When tacking with gas the joint edges can expand some

be prevented or allowed for.

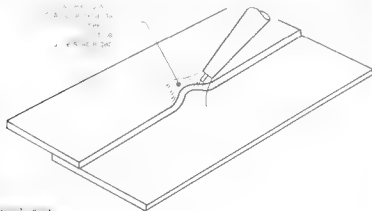
MMA tacks are made by striking an arc. This can be difficult, it flashes over the metal surface and the joint out of position if it is too high.

When tacking with MIG touch the point at which the arc is to be made and then pressing the torch away very quickly. Large MMA tacks are made by tacking the joint is necessary to build up rather than build up.

Fillet Joints

Stringer beads are deposited at 90 degrees and a tilt of 45 degrees to allow allowance for either regular or irregularities.

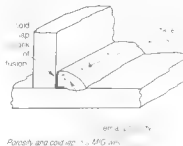
The leading edge of the weld



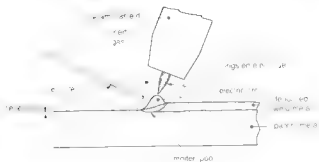
FAULT FINDING IN MIG WELDS



Fault	Cause
Crater at end of weld	Too fast
Crater in weld	Too fast
Crater at end of weld	Too fast
Crater in weld	Too fast
Crater at end of weld	Too fast
Crater in weld	Too fast
Crater at end of weld	Too fast
Crater in weld	Too fast



6 TIG WELDING



EQUIPMENT REQUIREMENTS

The equipment required for TIG welding is relatively simple. It consists of a power source, a torch, and a filler metal. The power source is the most important component, as it determines the type of welding that can be performed. There are two main types of power sources: AC and DC. AC power sources are used for welding non-ferrous metals, while DC power sources are used for welding ferrous metals. The torch is used to hold the electrode and to direct the arc. It is made of a refractory material and has a water-cooled body. The filler metal is a rod of the same material as the workpiece, which is used to fill the joint. It is held in the torch and melted by the arc to form the weld.

The power source is the most important component, as it determines the type of welding that can be performed. There are two main types of power sources: AC and DC. AC power sources are used for welding non-ferrous metals, while DC power sources are used for welding ferrous metals.

AC TIG Sets

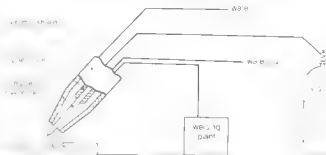
AC TIG sets are used for welding non-ferrous metals. They consist of a power source, a torch, and a filler metal. The power source is an AC power source, which provides the energy for the arc. The torch is used to hold the electrode and to direct the arc. The filler metal is a rod of the same material as the workpiece, which is used to fill the joint. It is held in the torch and melted by the arc to form the weld.

DC TIG Sets

DC TIG sets are used for welding ferrous metals. They consist of a power source, a torch, and a filler metal. The power source is a DC power source, which provides the energy for the arc. The torch is used to hold the electrode and to direct the arc. The filler metal is a rod of the same material as the workpiece, which is used to fill the joint. It is held in the torch and melted by the arc to form the weld.

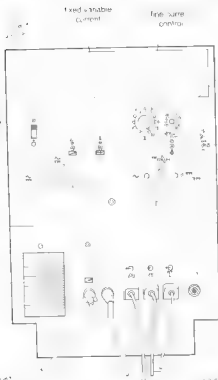
Features of TIG Welding Sets

TIG welding sets have several features that make them suitable for welding. They are portable, easy to use, and provide a high quality weld. They are also suitable for welding a wide range of materials.



TIG Welding

8. If you are using a TIG torch, you should use a TIG torch.
9. If you are using a TIG torch, you should use a TIG torch.
10. If you are using a TIG torch, you should use a TIG torch.
11. If you are using a TIG torch, you should use a TIG torch.
12. If you are using a TIG torch, you should use a TIG torch.



200 VAC
50/60 Hz

100 VAC
50/60 Hz

100 VAC
50/60 Hz

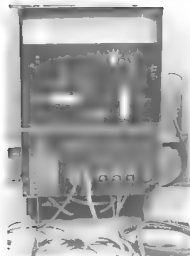
100 VAC
50/60 Hz

100 VAC
50/60 Hz

100 VAC

100 VAC

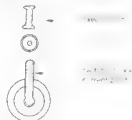
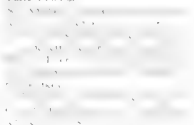
100 VAC



Polarity Switch



Current Control



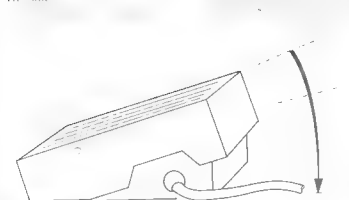
Foot Pedal

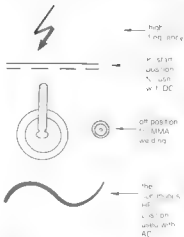


External Switch



III Switch





Gas and Water Control

For MMA welding, the gas and water control is set to the 'off' position.

For TIG welding, the gas and water control is set to the 'on' position.

For MIG welding, the gas and water control is set to the 'on' position.

For FCAW welding, the gas and water control is set to the 'on' position.

For SAW welding, the gas and water control is set to the 'on' position.

For Oxy-fuel welding, the gas and water control is set to the 'on' position.

For Laser welding, the gas and water control is set to the 'on' position.

For Electron beam welding, the gas and water control is set to the 'on' position.

For Friction stir welding, the gas and water control is set to the 'on' position.

For Ultrasonic welding, the gas and water control is set to the 'on' position.

For Resistance welding, the gas and water control is set to the 'on' position.

For Cold-chamber die casting, the gas and water control is set to the 'on' position.

For Hot-chamber die casting, the gas and water control is set to the 'on' position.

For Investment casting, the gas and water control is set to the 'on' position.

For Sand casting, the gas and water control is set to the 'on' position.

For Die casting, the gas and water control is set to the 'on' position.

For Centrifugal casting, the gas and water control is set to the 'on' position.

For Continuous casting, the gas and water control is set to the 'on' position.

For Stripped casting, the gas and water control is set to the 'on' position.

For Slab casting, the gas and water control is set to the 'on' position.

For Billet casting, the gas and water control is set to the 'on' position.

For Wire casting, the gas and water control is set to the 'on' position.

For Rod casting, the gas and water control is set to the 'on' position.

For Pipe casting, the gas and water control is set to the 'on' position.

For Tube casting, the gas and water control is set to the 'on' position.

For Sheet casting, the gas and water control is set to the 'on' position.

For Plate casting, the gas and water control is set to the 'on' position.

For Bar casting, the gas and water control is set to the 'on' position.

For Ingot casting, the gas and water control is set to the 'on' position.

For Castings, the gas and water control is set to the 'on' position.

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1.1.1 TIG or Scratch Start

The TIG or Scratch Start is a method of starting a TIG weld.

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The TIG or Scratch Start is a method of starting a TIG weld.

The TIG or Scratch Start is a method of starting a TIG weld.

cover



the arc starts
when the pressure is applied

Exhauster

The exhauster is a device which is used to draw the gas from the torch and into the exhaust system. It is a small, portable, and easy to use device. The exhauster is used to draw the gas from the torch and into the exhaust system. It is a small, portable, and easy to use device. The exhauster is used to draw the gas from the torch and into the exhaust system. It is a small, portable, and easy to use device.

desired height in a gas

Slope In - Out Settings

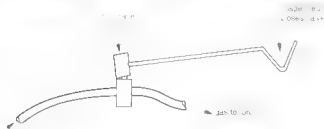
When the arc reaches the torch, and is extinguished, the torch is moved to the level set over and similarly the

Economizer

The economizer is a device which is used to control the flow of gas from the torch. It is a small, portable, and easy to use device. The economizer is used to control the flow of gas from the torch. It is a small, portable, and easy to use device. The economizer is used to control the flow of gas from the torch. It is a small, portable, and easy to use device.

Assembling the Equipment

Assuming the welder has a supply, the torch assembly the welder. The fittings are symbols or are self

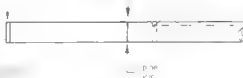


EQUIPMENT MAINTENANCE

PREPARING THE WORK

Cleaning

1. Clean the
workpiece
with a wire
brush.



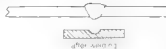
PREPARING TO WELD

Edge Preparation

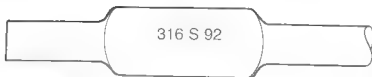
backing strip



backing bar



The Tungsten Electrode





20-30 point Thoriated for heavy metals with DC



Maximum current density should be found for with the smallest electrode that can be used without it melting. If the diameter is too large the arc wanders around the electrode end without focus and is difficult

to start.

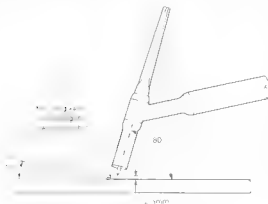
The diameter of the ceramic shroud is varied

to provide enough gas at a flow rate high enough to displace the air if economy dictates that the smallest possible is used with the slowest flow rate that adequately protects the weld pool.

Gas protection can be improved by using a gas lens which is located inside the shroud giving the gas directionality and much cleaner

MAKING A WELD BEAD USING DC

The torch is held at 80 degrees, pointing in the direction of travel, with the pointed end of the tungsten about 2 mm above the sheet surface. The filler wire is placed on the sheet surface about 10 mm away in readiness to add it to the pool and where it can be seen in the light of the arc.



TIG torch angles



Factor in Affecting the Jet ...
Welding Current

Welding Speed

can be kept under control, fast manual speeds are desirable because these produce the least distortion.

Arc Length

This is very susceptible to variation as the weld progresses, but the variation can be reduced by using the 'pencil' grip. Holding the torch from underneath, perhaps with the elbow of the gloved hand shading away the steel surface, is much more comfortable than a 'power' grip held above the torch. Used in gas welding.

Long arcs cause the arc to spread widely, with wide, shallow melting because of the drop in current. Since the shield wire distance also increases this may allow ingress of air and subsequent contamination of the weld. The arc should be as short as possible but when it is too short contamination of the

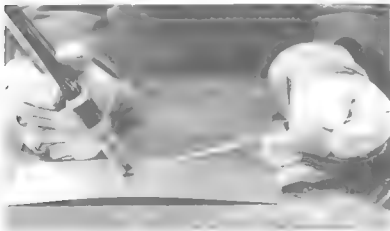
electrode is likely, although touching down can take work or misdirecting the wire into the narrow arc gap.

Restarting the Bead

Some types of stainless steel in particular may oxidise in the crater enough to necessitate grinding. Otherwise simply ensure that the crater's trace is fully melting before backing, filler and progressing.

Finishing the Weld Bead

At the end of the bead the crater is tilted in to prevent weakness cracking at this point. This is done by stopping up with filler wire, not as easy if the current is made to decay gradually, either with slope out or with the fast weld.



The best TIG torch grip for bench work

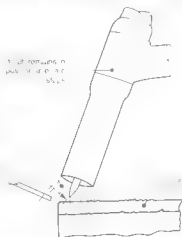
MAKING A BEAD USING AC

SHUTTING DOWN PROCEDURE

4. TIG torch

5. Electrode

6. Workpiece



back to the packet or, if uncertain about their identity, scrapping them.

MAKING TIG WELDED JOINTS

Most of the principles of producing good TIG welds have already been established and it should now simply be a matter of applying them and (a) following a joint line and (b) supplying the right amount of heat filler to produce a sound bead with a good profile.

Tacking

Tacks are made easily enough but the metal may distort either as it is heating or as a result of tacking. The amount of restraint required to prevent this happening will be learned

by experience. The care over cleanliness and rust is when welding is also required during tacking since the tacks are to become fused into the weld.

As they are approached and in contact plus they most easily on a prep using 'bridge tacks'. As the name implies are built up from each side until

tack bridges gap locally and is removed as weld approaches.

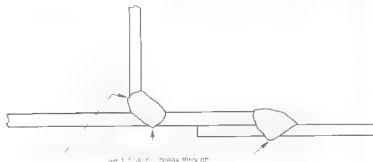


The bridge tack

to form a bridge across the upper part of the joint, joining the plate while still being easy to remove.

Fillers

In common with other welding processes, weld pool shrinkage should be observed to fuse into the correct at the back edge and up in the desired profile at the front.



leading edge. Some regulation of the current speed may be necessary to prevent the end breaking through the unwelded side of

The minimum requirement of any fusion cut is that it should be fused to all of the parent metal it is in contact with, but the bal-

ancing, the position and the arc. Establishing a voltage across the metal thickness sagging, sagging penetrating, the

B. m.

7 WELDING OTHER METALS

COPPER

Copper is a difficult metal to weld because of its high thermal conductivity, high melting point, and its tendency to form a brittle oxide layer on its surface. The most common method of welding copper is oxy-acetylene welding, which uses a flame to heat the metal and a filler metal to join the pieces. Other methods include TIG welding, MIG welding, and resistance welding.

Copper is a highly ductile metal, which means it can be bent or stretched without breaking. This property makes it useful for a wide range of applications, including plumbing, electrical wiring, and industrial machinery. However, its high thermal conductivity also makes it a challenge to weld, as the heat from the welding process can quickly dissipate into the surrounding metal.

ALUMINUM

Aluminum is a lightweight metal with a high strength-to-weight ratio, making it a popular choice for many industrial applications. It is also highly resistant to corrosion, which makes it ideal for use in marine environments. However, aluminum is also a difficult metal to weld because of its high thermal conductivity and its tendency to form a brittle oxide layer on its surface. The most common method of welding aluminum is TIG welding, which uses a non-consumable tungsten electrode to create a weld.

Oxy Acetylene Welding

Oxy-acetylene welding is a process that uses a flame to heat the metal and a filler metal to join the pieces. The flame is created by mixing oxygen and acetylene gases, which are then ignited. The filler metal is a rod of metal that is melted by the flame and used to fill the gap between the two pieces of metal. This method is commonly used for welding copper, aluminum, and steel.

MMA Welding

MMA welding, also known as shielded metal arc welding, is a process that uses a consumable electrode to create a weld. The electrode is coated with a flux that melts and forms a protective shield around the weld. This method is commonly used for welding steel and cast iron.

MIG Welding

MIG welding, or metal inert gas welding, is a process that uses a non-consumable tungsten electrode to create a weld. The electrode is surrounded by an inert gas that protects the weld from oxidation. This method is commonly used for welding aluminum, copper, and steel. It is a more precise method than oxy-acetylene welding, but it requires more skill and equipment.

ensuring a smooth bead when using a semi-automatic wire.



The push-out joint

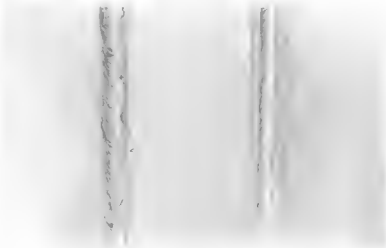
TIG Welding

TIG welding is a little slower than gas metal arc welding at times, but it gives results with MIG and TIG welding gases.

STAINLESS STEELS

There are many types of stainless steel, but three are the most common.

1. Austenitic
2. Ferritic
3. Martensitic

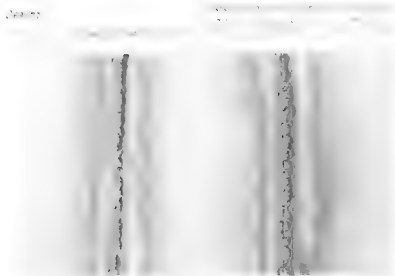


A MIG bead (left) and a TIG bead (right) on the surface of aluminum sheet.

Welding Other Metals



The Consumables



Welding torch and weld on metal surface.

MMA

Manual Metal Arc (MMA) welding is the most common method of joining metals. It involves using an electrode to create an arc between the electrode tip and the workpiece. The arc melts the metal, forming a weld pool. The electrode is then moved along the joint, creating a continuous weld. MMA welding is suitable for a wide range of metals, including steel, stainless steel, and aluminum. It is also used for repair work and fabrication.

MMA welding is a versatile technique that can be used in a variety of positions, including horizontal, vertical, and overhead. It is also suitable for welding in confined spaces. The main advantage of MMA welding is its portability and simplicity. It does not require a complex setup or specialized equipment. However, it is a labor-intensive process and requires a high level of skill and experience to produce high-quality welds.

MMA welding is commonly used in construction, manufacturing, and maintenance. It is used to join structural steel, reinforcement bars, and pipes. It is also used for welding machinery and equipment. MMA welding is a fundamental skill for any welder, and it is essential for many industrial and construction applications.

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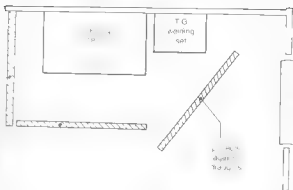
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TIG

Tungsten Inert Gas (TIG) welding is a precise and high-quality welding process. It involves using a non-consumable tungsten electrode to create an arc between the electrode tip and the workpiece. The arc melts the metal, forming a weld pool. The electrode is then moved along the joint, creating a continuous weld. TIG welding is suitable for a wide range of metals, including steel, stainless steel, and aluminum. It is also used for repair work and fabrication.



Diagram illustrating the TIG welding process.



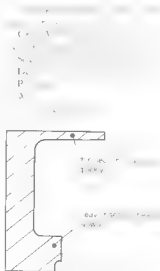
Site plan of TIG welding screens

CAST IRON

Items of complex shape and varying thicknesses but these are likely to heat/cool at very different rates. Combined with its low ductility, this makes cast iron very susceptible to cracking unless great care is taken to both heat and cool the metal evenly. The problem is aggravated by the high carbon content, which makes the metal even more brittle if cooled quickly.

Welding Procedure

Strip down to a 'single' component if



Welding with preheating and post-heating

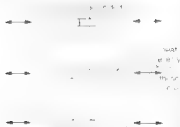
Production

Gas Braze Welding



Argon Arc Welding

MMA



Gas Fusion Welding

4. The process of gas fusion welding is a type of gas metal arc welding (GMAW) that uses a non-consumable electrode and a shielding gas to protect the weld pool. The process is typically used for joining metals that are difficult to weld using other methods.

MIG

TIG

Studding

The strength of thicker joints is improved by studding. Holes are drilled into the joint surface, tapped, and studs inserted. These are

DISSIMILAR METALS

Welding is not possible between the alloys and the "heavy" ones, so, for example, mechanical means or an adhesive is way to join stainless steel to aluminum.

Otherwise, if one of both metals is cast steel, then the filler should be stronger, higher alloyed material. D carbon steels can be welded with hydrogen electrode, while non fusible are best for combinations of high purity and steel.

Welded with copper wire
on the ends



Welded with
copper wire

Butt welded plates joined
with copper wire

Welded and tapered

Welded and tapered

Welded and tapered



8 DISTORTION CONTROL



Warping in sheet

BUCKLING



less volume of heat into the metal so MIG welds heat the metal less than gas metal arc welds. Large MMA electrodes less than small

1500 C and it cools

This is combined b

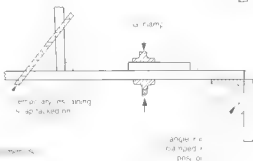
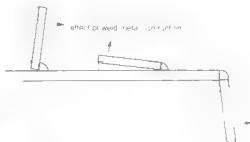
Alternatively a very low heat source can be used and/or welding can be stopped periodically for the metal to cool as necessary before recommencing.

the movement to pro

Restraint

1.5.5.5

ANGULAR DISTORTION



Distortion Control

Restraint can be built in by tacking as many items together as possible before starting to weld so that one piece of metal holds others in place. This can be achieved architecturally by tacking on cross braces or diagonal bracing up and then removing the braces afterwards.

Controlled Movement

can be used to advantage

Presetting

If a tilt is expected to pull over about 5 degrees, then setting it back 5 degrees before starting will cause it to be in the correct alignment when welded. Judgement is different for one offs but some presetting must improve the accuracy.

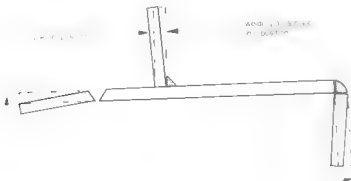
Weld Sequence

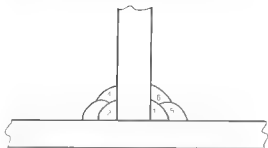
This is perhaps the most important and

interesting method at the time of welding on one side pulls it over then welding on the other side pulls it back again. The two forces are opposite and act on the previous weld but it is not as easy as it is said to counteract the pull and not make it twice as bad as if it is not completely pulled back. The second side may require a different weld sequence before returning to the first side. The welds are placed so that the direction of pull is in the direction required.

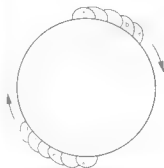
DESIGN

If welding produces a distortion then welding from a main joint location reduces the volume of weld possible. A practical weld area rather than one side





weld on opposite sides to counteract distortion



distortion is reduced by welding on opposite sides



welding on opposite sides of joint reduces distortion

Distortion Control



9 QUALITY IN WELDING

The overall performance of a welded joint will depend on four factors:

- 1 The type of material being welded
- 2 The consumables used to hold it together
- 3 The procedure used to make the joint
- 4 The skill of the welder making the joint

In order to have confidence and reliability in welded work standards are applied in all four areas, typically national ones like DIN in Germany, and BS in Britain, but moving rapidly towards ENs in Europe. Euro Norms are becoming universal across the EC and in Britain are prefixed by BS, for example, BS EN 10 025 is the standard applied for structural steels.

Materials and consumables are subject to quality control during manufacture to ensure compliance with various standards. Welding procedures and the welder's skill are assessed by making and testing specimen welds, which varies in difficulty to reflect particular areas of work. The welder is the most vulnerable part of the system, as his performance may be influenced by many factors. However, working to an established weld procedure should ensure that the joint is not distorted and that the weld is of the correct chemical composition and metallurgically acceptable in terms

of fusion with the parent metal it is in contact with, have no discontinuities or inclusions and a profile which blends smoothly with the parent metal.

WELD FAULTS AND THEIR CAUSES

Lack of Penetration

The weld fails to fuse fully into the root of a joint or through a butt joint. Probable causes are:

- 1 More heat is required – use a larger flame or higher current setting
- 2 Less filler is needed – use a smaller electrode, a slower feed speed, or in gas TIG welding, less gas
- 3 The joint gap is too small or the angle is incorrect

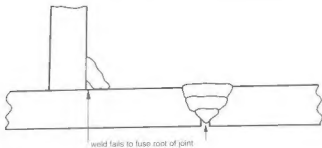
Over Penetration

The weld metal protrudes excessively through a joint or breaks through the other side of the joint. The causes are the opposite of those listed above for lack of penetration.

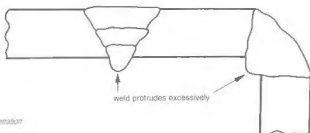
Lack of Fusion

The weld metal fails to fuse at the interface

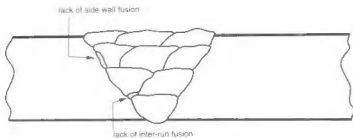
The weld must also be physically sound,



Lack of penetration



Overpenetration



Lack of fusion

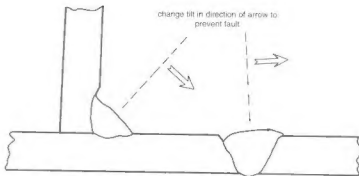
This has the same causes as lack of penetration and can be avoided by using more heat/less filler.

Undercut

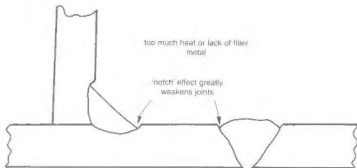
The metal has melted away but has not been

filled in, leaving a 'notch' at the side of the weld. Undercut on one side only indicates that the angle of tilt (of the torch/gun) did not bisect the joint angle.

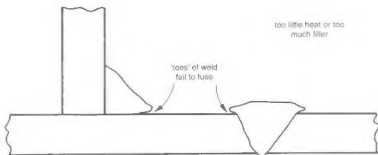
If it appears on both sides then the ratio of heat to filler must be reduced, that is, less heat or more filler is needed.



Undercut - on one side



Undercut - on both sides



Overlap

Overlap

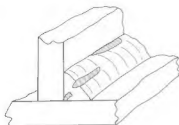
Not common, this is where weld metal spills over the plate surface without having fused to it. When this occurs on one side only, a change in tilt angle is needed, but if it happens on both sides then more heat or less filler is required.

Cold Lap

This is a term applied to MIG welding only but actually means lack of fusion/overlap. It is very difficult to eliminate completely, at restarts generally and at those in aluminium in particular. Higher voltage/wire settings are required or less wire/more voltage.

Slag Traps

These occur in MMA welding only and are voids in the weld metal occupied by slag. The causes are numerous and include a low current setting, acute preparation angle, steep electrode slope angle, or welding over slag or heavy scale.



Slag traps.

Porosity

Gas entrapment is rarely evident on the weld surface, but the traps' spherical form appears as light circles on an X-ray. This problem is caused in stick welding by damp electrode coatings (hydrogen) or in MIG/TIG welding by lack of gas shielding, or from contaminants such as oil and oxide scale.

Blowholes

These are gas holes large enough to appear

on the weld surface and may be due to extreme porosity, or in braze welding occur as a result of too little oxygen in the flame.

Underfill

Part of a butt weld is below the plate surface, causing it to fail any welding test. More filler/passess are required.

Splatter

Particles of weld thrown out on the plate

surface, caused by high welding currents, long arcs and damp electrodes in MMA welding, and by too little inductance, too much CO₂ in the shielding gas in MIG welding.

Rough Appearance

Erratic arc length, long arcs and shallow slopes give rise to rough welds, as do damp electrodes and surface contamination.

Acet
the h
the u
hydro
Alloy
at le
meta
Alter
elect
conn
Amp
for el
Arc
gap, v
electr
Arc v
an el
poss
Argon
used
Back
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techn
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